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Surface Water Quality

Prepared for

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July 1981

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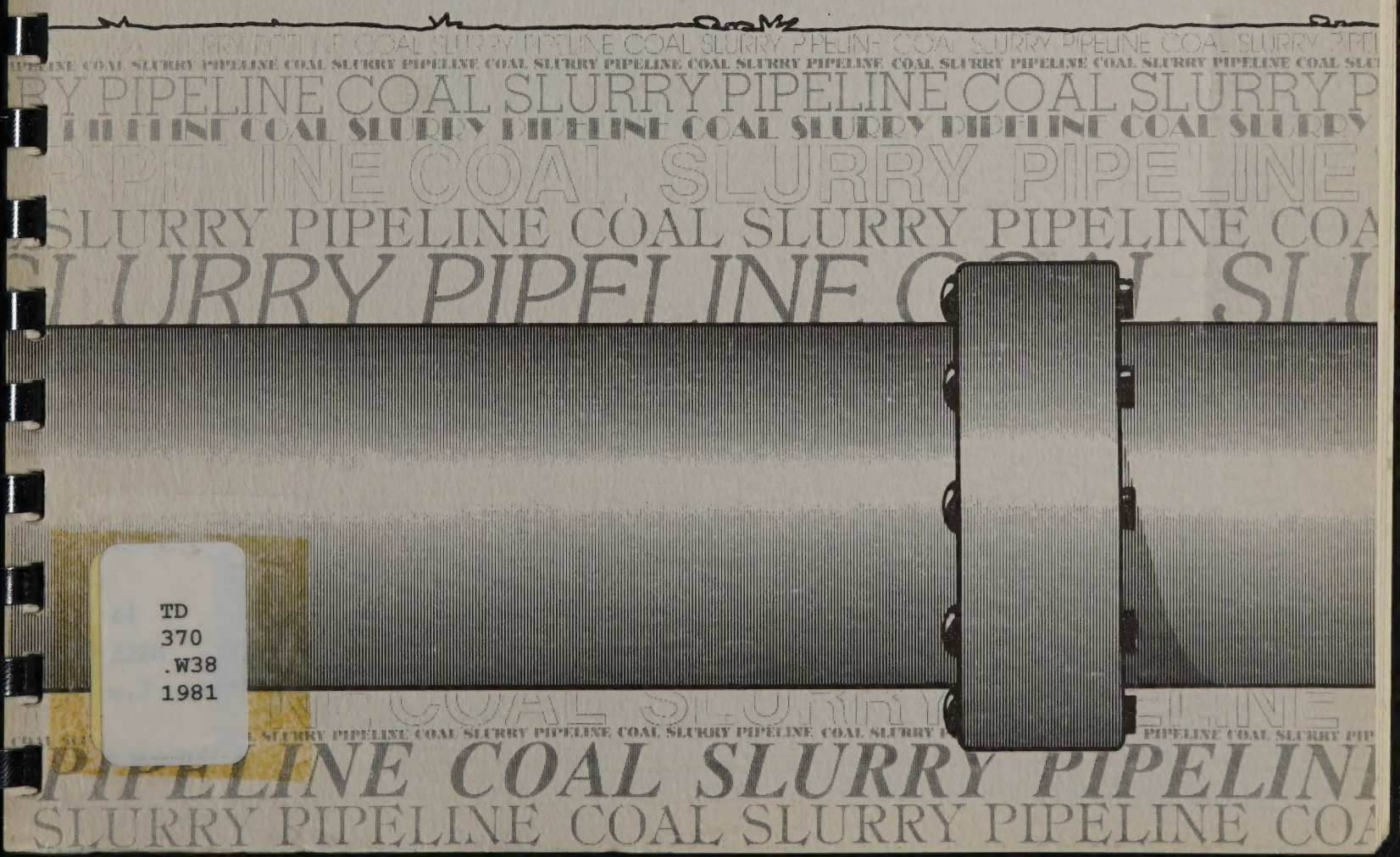

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WATER QUALITY TECHNICAL REPORT

for the

ETSI Coal Slurry Pipeline Project

July 1981

Prepared by Woodward-Clyde Consultants
for U.S. Department of Interior,
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SUMMARY

This technical report addresses potential significant effects on surface water quality that could result from construction or operation of the proposed and alternative pipeline systems. Principal conclusions are presented below.

DEWATERING PLANT EFFLUENT DISCHARGE

The coal slurry carrier water would be altered in chemical composition during coal transport. Simulation studies (simulated coal slurry transport of proposed coal and water sources) indicate that the levels of total dissolved solids (TDS) and sulfates (SO_4) would increase in the carrier water by 80 to 1100 milligrams per liter (mg/l) and up to 600 mg/l respectively. Under the water discharge alternative, state standards for these constituents could be exceeded at certain discharge locations. Additionally, the measured biochemical oxygen demand (BOD_5) could cause receiving water standards for dissolved oxygen to be exceeded. Therefore, treatment of the dewatering plant effluent would be required prior to discharge in order to meet established state standards. Uniform National (federal) Performance Standards for the control of coal slurry effluent discharge have not yet been promulgated. Final criteria have recently been published by the U.S. Environmental Protection Agency (EPA) for a list of 129 potentially toxic "priority pollutants." Simulation studies completed to date for these 129 pollutants indicate that the leaching (transport) of organic constituents from the coal into carrier water results in levels of organic constituents in the dewatering effluent below the limits of instrument detection except for two constituents whose presence (at low levels) is likely due to unavoidable sampling and analytical contamination during standard testing methods. Several trace metals were measured in the slurry filtrate, but were also at levels which could be effectively reduced by treatment to meet U.S. EPA drinking water standards.

STREAM CROSSINGS

Construction of the proposed or alternative pipeline system would result in a temporary increase in the levels of suspended solids (and resultant turbidity levels) downstream of trenching or dredging activities. Levels could exceed 10,000 mg/l at distances of 50 feet or less downstream of construction operations at perennial-river crossings. Measurable increases above background levels could be generated up to distances of 500 feet downstream of many perennial crossings, with measurable increases greater than 1000 feet downstream of dredging operations in major rivers. The majority of sediments would settle within several hundred feet downstream of most crossings. A small percentage of finer particles could travel farther downstream before settling to the bottom as bedload, which could be on the order of 500-1000 feet downstream at minor perennial rivers, 2000-3000 feet downstream in bayou waterways, and several miles downstream in major perennial rivers. The increase in level of suspended solids would be temporary in nature, would not exceed naturally occurring background levels (at crossings with available records), and would return to near background levels shortly after cessation of construction activities. Therefore a significant water quality alteration is not anticipated at crossing sites.

HYDROSTATIC TEST WATER DISCHARGE

Water would be used for hydrostatic testing of the pipeline. Up to an estimated maximum of 16 million gallons could be generated for the largest single discharge. The uncontrolled discharge of this volume of water could temporarily increase ambient surface water flow, potentially causing erosion, and principally increasing the levels of suspended solids and iron in local receiving waters, due to pipe coating and other debris, and possibly increasing the levels of oil and grease.

STREAMFLOW REDUCTIONS

Reductions in flow to several South Dakota and Wyoming streams and rivers has been estimated to occur as a result of Madison groundwater pumping. Surface water quality effects resulting from worst case flow reductions could include slight increases in temperature and dissolved constituents and decrease in dissolved oxygen, and reduction in waste assimilative capacity (e.g., lower available dilution) of affected streams or rivers. Two existing wastewater dischargers could be affected by a reduction in waste assimilative capacity: The city of Hot Springs, South Dakota, and the town of Hulett, Wyoming.

Chapter 1
SLURRY DEWATERING PLANT EFFLUENT DISCHARGE

The proposed coal slurry pipeline system and alternatives would include dewatering plants at 12 locations. It is proposed that the dewatering plant effluent (water removed from the slurry) would be delivered to individual power plants for use as makeup water. As an alternative disposal method, slurry effluent would be discharged into local surface waters. This section of the technical report will evaluate the potential water quality effects associated with this alternative disposal method.

1.A DISCHARGE LOCATIONS

Twelve alternative water discharge sites are located on rivers in Oklahoma, Arkansas, and Louisiana. As shown in Table 1-1, these include four sites on the Mississippi River, three sites on the Arkansas River, and one site each on the Verdigris, White, Neosho, Calcasieu, and Red rivers. Table 1-2 presents the rates of discharge for each of the alternative systems at each discharge site.

1.B RECEIVING WATER CHARACTERISTICS

Receiving-water characteristics vary from site to site and seasonally at individual sites. Table 1-3 presents receiving-water flow data. Table 1-4 presents a range of values for several water quality parameters, recorded at the upstream or downstream U.S. Geological Survey (USGS) gaging station closest to each of the alternative discharge sites over the period 1970-1978. The maximum concentrations, shown in Table 1-4, normally occur during periods of lowest stream flow. The maximum concentration at minimum flow is of greatest significance in evaluating the potential water quality effects upon receiving waters.

TABLE 1-1

LOCATION OF ALTERNATIVE DISCHARGE SITES

Site	Discharge Location
Ponca City (Oklahoma)	Arkansas River, 29 miles downstream of Ponca City
Pryor (Oklahoma)	Neosho River (Grand River), 40 miles upstream of confluence with Arkansas River
Oologah (Oklahoma)	Verdigris River, below Oologah Dam
Muskogee (Oklahoma)	Arkansas River, 4 miles downstream of confluence with Neosho River (Grand River)
Independence (Arkansas)	White River, 20 miles downstream from Lock 4, Dam 1, at Batesville
White Bluff (Arkansas)	Arkansas River, 25 miles downstream of Little Rock, between Lock Dams 5 and 6
Cypress Bend (Arkansas)	Mississippi River, Louisiana state line and Arkansas River, 25 miles upstream from Greenville
New Roads (Louisiana)	Mississippi River, 35 miles upstream of Baton Rouge, Louisiana
Baton Rouge (Louisiana)	Mississippi River at Baton Rouge, Louisiana
Lake Charles (Louisiana)	Calcasieu River, Lake Charles, Louisiana
Boyce (Louisiana)	Red River, 3 miles upstream from Boyce, Louisiana
Wilton (Louisiana)	Mississippi River, 13 miles downstream from Donaldsonville, Louisiana

TABLE 1-2

SLURRY EFFLUENT DISCHARGE RATES

Discharge Location	Maximum Instantaneous Discharge (cfs)[a]			
	Proposed Action (cleaned coal)	Proposed Action (uncleaned coal)	Market Alternative	Barge Alternative
Ponca City	5.4	5.4	-	-
Pryor	2.4	2.4	4.3	4.3
Oologah	-	-	2.8	2.8
Muskogee	4.1	4.1	-	-
Independence	4.1	4.1	4.1	4.1
White Bluff	4.1	4.1	4.1	4.1
Cypress Bend	-	-	-	15.1
New Roads	1.6	1.6	1.6	-
Baton Rouge	-	-	4.7	-
Lake Charles	3.3	3.3	3.3	-
Boyce	1.5	1.5	1.5	-
Wilton	4.1	4.1	4.1	-

[a]Average annual discharge would be slightly less than the instantaneous maximum due to system downtime and other factors.

TABLE 1-3

RECEIVING STREAM FLOW DATA

Site	Receiving Stream	USGS Station No.	Location of Station Relative to Site		Mean Discharge (cfs)	Average Yearly Flow (ac-ft/yr)	Minimum Discharge (cfs)
Ponca City	Ark. R.	07152500	23.4	mi downstream	4,826	3,496,000	14
Oologah	Verdigris R.	07171400	0.5	mi upstream	2,958	2,143,000	-0-
Pryor	Neosho R.	07191500	7.8	mi upstream	8,067	5,845,000	12[a]
Muskogee	Ark. R.	Combined Data		b	18,576	13,455,000	39
Independence	White R.	Difference in 2 gages		c	14,265	10,335,000	1,140
White Bluff	Ark. R.	07263450	33.0	mi upstream	40,950	29,670,000	850
Cypress Bend	Miss. R.	07265450	50.0	mi downstream	547,200	396,400,000	88,200
Boyce	Miss. R.	07355500	23.0	mi downstream	31,870	23,090,000	873
New Roads	Miss. R.	07295100	46.7	mi upstream	522,200	378,830,000	85,000
Baton Rouge	Miss. R.	07295100	74.0	mi upstream	522,200	378,830,000	85,000
Wilton	Miss. R.	07295100	200.0	mi upstream	522,200	378,830,000	85,000
Lake Charles	Calcasieu R.	08015500	67.0	mi upstream	2,573	1,860,000	136

[a]Minimum flow occurred at time of upstream dam closure.

[b]Sum of three gages: 07164500, on Arkansas River; 07193500, on Neosho River; and 07176000, on Verdigris River.

[c]07072500, on Black River; and 07074500, on White River.

TABLE 1-4

WATER QUALITY CHARACTERISTICS AT DISCHARGE SITES

Parameter	Discharge Site											
	Ponca City	Pryor	Oologah	Muskogee	Independence	White Bluff	New Roads	Baton Rouge	Lake Charles	Boyce	Wilton	Cypress Bend
TDS (mg/l)												
Maximum	9150	217	1510	1644	197	494	288	316	8770	--	489	316
Minimum	133	131	109	152	--	--	--	--	23	--	147	151
Mean	1030	166	334	544	158	268	217	224	631	629	226	224
SO_4 (mg/l)												
Maximum	465	140	730	1000	14	58	90	81	650	240	85	91.0
Minimum	6.2	6.0	8.4	21	0	--	--	--	30	10	28	35.0
Mean	137	35	52	79	5.1	35	48	48	47	45	46	54.4
Cl (mg/l)												
Maximum	1700	668	280	819	8.0	220	53	170	4900	370	63	49.0
Minimum	15	1	0	7	3.5	--	--	--	3.6	12	12	2.0
Mean	369	33	60	212	5.3	78	20	26	321	69	22	20.0
DO (mg/l)												
Maximum	20	15	16	14.5	13.8	--	--	12.8	10.9	12.3	13.7	13.4
Minimum	5.8	6.0	5.1	5.5	6.4	6.1	5.9	5.9	3.6	4.8	5.6	6.2
Mean	10.1	9.1	9.6	10.3	10.0	9.2	8.8	8.6	7.2	8.4	8.6	8.8
pH												
Maximum	9.9	9.1	9.7	9.0	8.4	8.4	8.2	8.2	8.0	8.8	8.3	8.2
Minimum	6.0	6.9	6.4	7.0	7.5	6.1	7.3	6.8	4.9	6.2	6.6	7.2
Mean	8.1	7.7	7.7	8.0	8.1	7.7	7.7	7.6	6.6	7.4	7.6	7.8

Source: U.S. Geological Survey, 1970-1978.

1.C WATER SOURCE CHARACTERISTICS

Five water sources are under consideration for the proposed project. These include three Madison aquifer well fields in Wyoming (Crook County, Niobrara County, and the Gillette well field), and the Oahe Reservoir in South Dakota. An additional water source, the use of reclaimed waste-water, is also under consideration (as discussed in Section 1.I).

A preliminary review of the water quality characteristics of the Madison aquifer has been completed (Eisen et al. 1980) based upon historic well data and recent sampling programs on Madison wells. A complete description of the geology and geochemistry is found in the Well-Field Hydrology Technical Report (WCC 1981). Major ions in solution near the recharge areas include calcium, magnesium, and bicarbonate, with levels of sulfate and sodium increasing in concentration towards the deeper portions of the basin. This trend is evidenced in comparisons of samples taken from Crook County with samples from Niobrara County to the south (Eisen et al. 1980).

> Niobrara County Madison wells produce water slightly over 500 mg/l in TDS, with chloride concentrations increasing to 30-40 percent of the total anion composition. These mixed anion waters (35-40 percent HCO_3, 30-40 percent Cl, 25-30 percent SO_4) identify ground water that is chemically different from Madison water to the north. Crook County water wells, with the exception of the Sundance well, produce water with higher TDS and sulfate concentrations than Madison waters to the south. This increase directly correlates with distance from outcrop areas and therefore longer ground-water flow paths. . . .Crook County Madison wells are codominated by sulfate and bicarbonate ions. Chloride comprises less than 10 percent of the total anion composition.
>
> Whereas some trends in the major ion concentrations from Madison water wells are noticeable, no dramatic differences are found. The total range in TDS from these wells is 236 to 1060 mg/l, with most concentrations averaging about 500 mg/l. These variations are mainly caused by differing amounts of dissolved calcium sulfate. Much greater variations are found in the overlying Minnelusa Formation.

For the Niobrara and Crook County well-field alternatives, the carrier water (Madison aquifer ground water) would be altered over the fifty-year

project lifetime due to induced ground-water movement accompanying pumping. Ground-water modeling investigations completed on the Madison aquifer (Wood ward-Clyde Consultants 1980a) indicate that the level of total dissolved solids, sulfates, and chlorides (three standard specific parameters) would reach the levels shown in Table 1-5.

Water quality in the Oahe Reservoir is recorded at the Oahe Dam (Station #46CE01) as well as 5.8 miles downstream at the USGS gaging station near Pierre, South Dakota. Based upon recent station records, Oahe Reservoir water quality is characterized by TDS levels of up to 490 mg/l, SO_4 levels of up to 220 mg/l, and Cl levels of up to 11 mg/l (CH_2M Hill et al. 1978).

1.D COAL SOURCE CHARACTERISTICS

Coal would be mined from five sites in Campbell County, Wyoming. Coal composition data are summarized in Table 1-6, which includes data from the USGS computer retrieval system (Carey 1980) for nine sites in Campbell County. In addition to the horizontal variability of the source coal, the chemical composition of Wyodak-seam coal at the Black Thunder site has been shown (Drever et al. 1977) to vary significantly in the vertical direction, with several trace elements strongly enriched at the upper and lower margins of the Wyodak seam. Although the elements sampled are all enriched at the interface region, correlations are not close between the concentrations of individual pairs of elements, or between individual elements and sulfur or ash content (Drever et al. 1977). Table 1-7 presents the highest reported concentrations of several trace metals present at depths of approximately 80 to 150 feet.

1.E SLURRY EFFLUENT CHARACTERISTICS

The quality characteristics of the slurry effluent would depend upon a number of factors, including the characteristics of the source coal and water, the degree of processing or treatment during dewatering, and the detention time, or travel time, in the pipeline. The detention time may, however, be a negligible

TABLE 1-5

ESTIMATED WATER QUALITY OF SOURCE CARRIER WATERS OVER THE PROJECT LIFETIME (50 years of pumping)

Water Source	Estimated Water Quality (mg/l) TDS	SO_4	Cl
Plan 1: Niobrara County Well Field	560	170	70
Plan 3: Crook County Well Field	910	460	50
Plan 2: Niobrara County Well Field plus Gillette Well Field	560	200	50
Plan 4: Crook County Well Field plus Gillette Well Field	825	410	40
Plan 5: Crook County Well Field plus Niobrara County Well Field	735	315	60
Plan 6: Crook County Well Field plus Niobrara County Well Field (Probable Case)	700-735	290-315	60
Oahe Reservoir	490	220	11
Treated Wastewater[a]	900	310	150

[a]Based a flow weighted average from one sample taken at existing wastewater discharge sources (see Table 4-38 FEIS).

TABLE 1-6

TRACE ELEMENT CONTENT OF NINE COAL ASH SAMPLES TAKEN FROM THE WYODAK SEAM IN CAMPBELL COUNTY, WYOMING

Element	Reported Range in Concentration (ppm)[b]	Element	Reported Range in Concentration (ppm)[b]
Silver (Ag)	0.0	Neodymium (Nd)	0.0
Arsenic (As[a])	1.0-3.0	Nickel (Ni)	20.0-70.0
Gold (Au)	0.0	Lead (Pb)	30.0-40.0
Boron (B)	300.0-700.0	Palladium (Pd)	0.0
Barium (Ba)	3000.0-7000.0	Phraseodymium (Pr)	0.0
Beryllium (Be)	0.0-5.0	Platinum (Pt)	0.0
Bismuth (Bi)	0.0	Rhenium (Re)	0.0
Cadmium (Cd)	1.0-1.4	Antimony (Sb[a])	0.1-0.7
Cerium (Ce[a])	0.0	Scandium (Sc)	15.0-30.0
Cobalt (Co)	15.0-30.0	Selenium (Se[a])	0.7-6.7
Chromium (Cr)	70.0-100.0	Samarium (Sm)	0.0
Copper (Cu)	104.0-216.0	Tin (Sn)	0.0
Erbium (Er)	0.0	Strontium (Sr)	700.0-2000.0
Europium (Eu)	0.0	Tantalum (Ta)	0.0
Fluorine (F)	45.0-65.0	Tellurium (Te)	0.0
Gallium (Ga)	20.0-50.0	Thorium (Th[a])	3.0-3.3
Gadolinium (Gd)	0.0	Titanium (Ti)	0.0
Germanium (Ge)	0.0	Thalium (Tm)	0.0
Hafnium (Hf)	0.0	Uranium (U)	0.2-0.97
Mercury (Hg[a])	0.08-0.29	Vanadium (V)	150.0-300.0
Indium (In)	0.0	Tungsten (W)	0.0
Lanthanum (La)	70.0-100.0	Yttrium (Y)	30.0-70.0
Lithium (Li)	25.0-48.0	Ytterbium (Yb)	3.0-7.0
Manganese (Mn)	190.0-500.0	Zinc (Zn)	36.0-218.0
Molybdenum (Mo)	0.0-15.0	Zirconium (Zr)	150.0-300.0
Niobium (Nb)	20.0-30.0		

Source: U.S. Geological Survey 1980.

[a] Whole coal.

[b] Concentrations measured by spectrographic analysis of ash samples.

TABLE 1-7

TRACE ELEMENT CONTENT OF COAL ASH SAMPLES TAKEN FROM THE BLACK THUNDER MINE, WYOMING

Element	Concentration[a] (ppm)	Element	Concentration[a] (ppm)
Arsenic (As)[b]	0.02-1.0	Molybdenum (Mo)	1.-5.3
Beryllium (Be)	0.09-3.6	Lead (Pb)	4-19
Cadmium (Cd)	0.3-2.0	Uranium (U)	0.06-3
Copper (Cu)	3-26		
Mercury (Hg)[b]	0.04-0.37		

Source: Drever, et al. 1977.

[a] Concentrations measured in samples taken in coal seam at depths of 79 to 146 feet.

[b] Determined on unashed coal.

factor. Moore (1979) and Manahan and Godwin (1979) have shown that equilibrium conditions for the leaching of inorganic minerals and heavy metals from coal to carrier water are established rapidly, or within the first 24 hours of anaerobic travel time.

The water quality characteristics of dewatered coal slurry have been analyzed by several investigators. Tests for 23 parameters have been carried out at the operating Black Mesa Coal Slurry Pipeline by Southern Utah State Water Laboratory (Science Applications Inc. 1977). Montana State University (Peavy et al. 1979) has simulated the quality alteration in coal slurry mixtures in a 1500-foot pipeline loop. Coal from Colstrip, Montana, was slurried with municipal drinking water and artificial saline makeup water, and the slurry filtrate was tested for 17 parameters. The University of Arkansas (Moore 1979, Keogh 1978) has presented results of water quality analyses carried out on Gillette, Wyoming, coal, using reclaimed wastewater, under both aerobic and anaerobic conditions. The University of Missouri (Manahan and Godwin 1979) has published the results of an investigation of the alteration in levels of 10 metals, resulting from simulated slurry conditions using distilled water and coal from the Powder River Basin, Wyoming. Finally, UCLA/SAI (1978) has presented the results of investigations on artificial saline solution slurried with coal from the Wasatch Plateau, Utah.

To initially evaluate coal slurry filtrate characteristics, Table 1-8 summarizes the results, for several parameters, of the coal slurry water quality testing performed to date under anaerobic conditions. These test results indicate that the transport of coal by slurry may produce a slightly acidic filtrate which may be higher in concentration than the source carrier water for total dissolved solids and conductivity, hardness and alkalinity, and levels of sulfate, calcium, magnesium, iron, manganese, zinc, and lead. Levels of other trace metals that have been evaluated do not appear to be leached in significant quantities into the carrier water (Manahan and Godwin 1979).

Recent analyses (UCLA/SAI 1978) have indicated that reportable quantities of organic constituents, principally alkyl substituted napthalenes, anthracene, phenanthrene, and floranthrene may be leached into the slurry carrier water.

TABLE 1-8

PUBLISHED COAL SLURRY SIMULATION TEST RESULTS

Parameter (units)	Investigator	Coal Type	Water Type	Water Quality Analyses		
				Source Water	Slurry Filtrate	Ratio Filtrate/ Source
pH	U. Arkansas	Wyodak, WY	Wastewater	6.6	7.0	1.1
	U. Missouri	Wyodak, WY	Distilled	7.0	4.4	0.6
	Montana St.	Colstrip, MN	Saline	8.3	6.3	0.8
	Montana St.	Colstrip MN	Municipal	7.8	-	-
	UCLA/SAI	Wasatch, UT	Distilled	8.3	6.8	0.8
Alkalinity (mg/l C_aCO_3)	U. Arkansas	Wyodak, WY	Wastewater	90	65	0.7
	Montana St.	Colstrip, MN	Municipal	97	558	5.8
	Montana St.	Colstrip, MN	Saline	96	385	4.0
	Black Mesa	Arizona	Ground water	93	829	8.9
Total Hardness (mg/l C_aCO_3)	U. Arkansas	Wyodak, WY	Wastewater	350	450	1.3
	UCLA/SAI	Wasatch, UT	Saline	280	510	1.8
	Black Mesa	Arizona	Ground water	22	72	3.3
Conductivity (mmhos)	Montana St.	Colstrip, MN	Municipal	197	1,940	9.8
	Montana St.	Colstrip, MN	Saline	5240	49,100	9.4
Chemical Oxygen Demand (COD) (mg/l)	U. Arkansas	Wyodak, WY	Wastewater	140	160	1.1
	U. Missouri	Wyodak, WY	Distilled	0	150	-
	Montana St.	Colstrip, MN	Municipal	3.4	13.8	4.1
	UCLA/SAI	Wasatch, UT	Distilled	0	3	-
Bichemical Oxygen Demand (BOD_5) (mg/l)	U. Arkansas	Wyodak, WY	Wastewater	20	90	4.5
	U. Arkansas	Wyodak, WY	Distilled	0	320	-

TABLE 1-8 Continued

Parameter (Units)	Investigator	Coal Type	Water Type	Water Quality Analyses: Source Water	Slurry Filtrate	Ratio Filtrate/ Source
Total Dissolved Solids (TDS) (mg/l)	UCLA/SAI	Wasatch, UT	Saline	2200	1700	0.8
	Black Mesa	Arizona	Ground water	150	1400	9.3
Sulfate (SO_4) (mg/l)	Montana St.	Colstrip, MN	Municipal	12	960	80.0
	Montana St.	Colstrip, MN	Saline	2080	1750	0.8
	UCLA/SAI	Wasatch, UT	Saline	470	510	1.1
	Black Mesa	Arizona	Ground water	16	130	8.1
Chloride (Cl)	Montana St.	Colstrip, MN	Municipal	4.1	4.3	1.0
	Montana St.	Colstrip, MN	Saline	5200	13,600	0.9
	UCLA/SAI	Wasatch, UT	Saline	530	460	0.9
	Black Mesa	Arizona	Ground water	14	81	5.8
Calcium (Ca)	U. Missouri	Wyodak, WY	Distilled	0	552	-
	UCLA/SAI	Wasatch, UT	Saline	230	100	0.4
	Black Mesa	Arizona	Ground water	6.9	23	3.3
Magnesium (Mg)	U. Missouri	Wyodak, WY	Distilled	0	552	-
	UCLA/SAI	Wasatch, UT	Saline	51	52	1.0
	Black Mesa	Arizona	Ground water	1.2	3.7	3.1
Iron (Fe)	U. Missouri	Wyodak, WY	Distilled	0	0.3	-
	UCLA/SAI	Wasatch, UT	Saline	0	0.02	-
	Black Mesa	Arizona	Ground water	0.065	0.53	8.2

TABLE 1-8 Concluded

Parameter (Units)	Investigator	Coal Type	Water Type	Water Quality Analyses: Source Water	Slurry Filtrate	Ratio Filtrate/ Source
Aluminum (Al)	U. Missouri	Wyodak, WY	Distilled	0	1.4	-
	Black Mesa	Arizona	Ground water	0.01	0.54	54
Manganese (Mn)	U. Missouri	Wyodak, WY	Distilled	0	2.4	-
	Montana St.	Colstrip, MN	Municipal	0.01	0.66	66
	Montana St.	Colstrip, MN	Saline	0.04	4.36	109
Zinc (Zn)	U. Missouri	Wyodak, WY	Distilled	0	0.16	-
	Montana St.	Colstrip, MN	Municipal	0.02	0.04	2
	Montana St.	Colstrip, MN	Saline	0.10	0.74	7.4
	UCLA/SAI	Wasatch, UT	Saline	0	0.004	-
	Black Mesa	Arizona	Ground water	0.006	0.004	0.7
Lead (Pb)	Montana St.	Colstrip, MN	Municipal	0.006	0.045	7.5
	Montana St.	Colstrip, MN	Saline	0.038	0.030	0.8
	UCLA/SAI	Wasatch, UT	Saline	0	0.06	-
	Black Mesa	Arizona	Ground water	0.001	0.06	60

Specific organic parameters were not evaluated by UCLA/SAI (1978). Tests conducted for biochemical oxygen demand, which included seeding coal slurry mixtures with either municipal wastewater or soil, indicated that slurry filtrates may also exert a measurable biochemical oxygen demand (Moore 1979).

The tests reported in the literature to date do not indicate a consistent alteration in carrier water quality due to the variable coal/water combinations used in particular investigations. Because of this variability, actual project-specific simulation investigations were necessary to more accurately estimate the quality characteristics of dewatering plant effluent discharge. Therefore, simulated coal slurry transport studies have been performed by Bechtel Inc., using project-specific coal and water sources. Coal samples taken from the Jacobs Ranch and Black Thunder mines have been crushed to project design size classifications, mixed with water samples from both the Madison aquifer and Oahe Reservoir, and mixed on mechanical rollers over a 15-day period to simulate maximum pipeline transport time. Following vacuum filtration, the filtrate has been analyzed for a number of chemical and biochemical parameters. A complete description of these investigations can be found in Plummer (1980a, 1980b, and 1981). Tables 1-9 through 1-12 present a summary of preliminary results available to date.

As shown, total dissolved solids (up to 1500 mg/l) and sulfate (up to 800 mg/l) could occur in the proposed (or alternative) carrier water. The slurry filtrate could exert a five-day biochemical oxygen demand (BOD_5) up to approximately 165 mg/l; dissolved oxygen would be virtually absent in the slurry filtrate.

The levels of TDS, SO_4, and Cl have been estimated to increase in the carrier water during the project lifetime (Table 1-5). The ETSI coal slurry wastewater quality will be a function of a number of factors, including the formation from which the raw water used in the pipeline is extracted, coal processing procedures (e.g., source mine, coal storage conditions, and storage duration), quantities of substances leached from the coal, and the number of years the raw water has been pumped from a given well field. Based on the coal slurry pipeline simulation tests (Tables 1-9 to 1-12), an estimation of typical

TABLE 1-9

TABULATION OF COAL SAMPLES AND
WATER SAMPLES TESTED IN VARIOUS SIMULATION RUNS

Simulation Run	Source of Water	Water Sample	Source of Coal	Coal Sample	Age of Coal Sample
1	ETSI well M-1	422	Black Thunder	456-1	Fresh
2	ETSI well M-1	422	Kerr-McGee	456-2	Fresh
3	ETSI well M-14	470	Kerr-McGee	467	Fresh
4	Oahe Reservoir	473-1	Kerr-McGee	467	Fresh
5a	ETSI well M-14	470	Kerr-McGee	467	3 mos
5b	ETSI well M-14	470	Kerr-McGee	467	3 mos
6a	Distilled water	--	Black Thunder	490	Fresh
6b	Upton 4	489-1	Black Thunder	490	Fresh
6c	Devils Tower	489-2	Black Thunder	490	Fresh
7a	Upton 4	489-1	Black Thunder	490	2 mos
7b	Upton 4	489-2	Black Thunder	490	2 mos

Source: Plummer 1981.

TABLE 1-10

SUMMARY OF FILTRATE TEST RESULTS

Test Number	1	2	3	4	5a	5b	6b	6c	7a	7b
Cations (mg/l as $CaCO_3$)										
Sodium	181	156	113	152	109	118	300	313	392	335
Potassium	14	25	16	18	18	24	9	10	10	9
Calcium	267	499	337	320	509	564	70	80	169	85
Magnesium	152	296	198	181	329	288	45	45	111	50
TOTAL	614	976	664	671	965	994	424	448	682	479
Anions (mg/l as $CaCO_3$)										
Nitrates	0	0	0	1	0	1	1	0	0	0
Chloride	45	45	8	15	4	2	5	3	3	4
Sulfates	482	736	404	479	795	783	246	294	626	310
Bicarbonates	87	195	252	176	166	208	172	151	53	140
TOTAL	614	976	664	671	965	994	424	448	682	479
TDS (mg/l)	867	1337	916	903	1406	1520	602	625	988	695
pH	7.8	7.8	8.0	7.8	6.6	6.0	7.9	7.7	7.4	7.8
TOC (mg/l)	31	37	71	50	96	129	41	37	25	40
BOD_5 (mg/l)	N/A	N/A	134	80	140	165	43	37	19	52
COD (mg/l)	109	92	180	137	205	275	79	73	50	61
Significant Metals										
Copper (µg/l)	9.9	<3	21	55	21	91	<3	14	N/A	N/A
Nickel (µg/l)	<1	110	25	19	8	8	11	<2		
Zinc (µg/l)	<1	160	20	50	38	53	30	9		
Manganese (µg/l)	<2	28	230	<3	140	210	<4	<4		
Iron (µg/l)	<2	<2	5	10	<3	4	200	300		
Coal Source	Black Thunder	Kerr-McGee	Kerr-McGee	Kerr-McGee	Kerr-McGee	Kerr-McGee	Black Thunder	Black Thunder	Black Thunder	Black Thunder
Comments:	Fresh sample	Fresh sample	Fresh sample	Fresh sample	Same as 3 & 4 3 mos later		Fresh sample	Fresh sample	2 mos old (old grind)	2 mos old (new grind)

Source: Plummer 1981.

N/A = not tested.

TABLE 2-3
SUMMARY OF SLURRY LEACH TEST RESULTS

Test No.	Coal Sample	Sample I.D.	Water Source TDS[1]	Water Source TC/TA[2]	Water Source Cond.[3]	Leach Results - Final Analysis TOC	COD	BOD (Filt.)[4]	TDS (mg/l)	TDS %Incr.	TC/TA (mg/l)	TC/TA %Incr.	Cond. (mmhos)	TOC	COD	No. of Days	BOD (Unfilt.)	BOD (Filt.)	BOD (4,5)
1.	Black Thunder Mine	ETSI #422	470	385	715	<5	5	--	867	84%	614	59%	1160	31	109		--	--	--
2.	Kerr-McGee Jacobs Ranch Mine	ETSI #422	470	385	715	<5	5	--	1337	184%	976	154%	1650	37	92		--	--	--
3.	Kerr-McGee Jacobs Ranch #467	ETSI #470 (Niobrara) Well M-14	471	402	657	5	6.3	--	916	94%	664	65%	1130	71	180	(5)	134	124	110
																(20)	173	147	136
																(30)	284	248	143
4.	Kerr-McGee Jacobs Ranch #467	ETSI #473-1 (Oahe)	544	431	793	8	19	--	903	66%	670	55%	1240	50	137	(5)	--	80	--
																(20)	--	100	--
																(30)	--	110	--
5a.	Kerr-McGee Jacobs Ranch #467	ETSI #470 (Unheated)	433	390	682	4	6	(5) 11	1406	225%	965	147%	1650	96	205	(5)	--	140	--
								(20) 14								(20)	--	175	--
								(30) 17								(30)	--	197	--
5b.	Kerr-McGee Jacobs Ranch #467	ETSI #470 (Heated)	415	390	642	5	9	(5) 9	1520	266%	994	155%	1690	129	275	(5)	--	165	--
								(20) 17								(20)	--	216	--
								(30) 18								(30)	--	240	--
6a.	Black Thunder	ETSI #490	Distilled Water			--	--	--	416	--	258	--	555	41	84	(5)	--	45	--
6b.	Black Thunder	#490	476	(#489-1) 392	654	11	<5	(5) 4	602	26%	424	8%	862	41	79	(5)	--	43	--
6c.	Black Thunder	#490	549	(#489-2) 444	677	16	<5	(5) 2	625	14%	448	1%	884	37	73	(5)	--	37	--
7a.	Black Thunder	#490	476	392	654	11	<5	(5) 4	988	107%	682	74%	1300	25	50	(5)	--	19	--
																(20)	--	31	--
																(30)	--	38	--
7b.	Black Thunder	#490	476	392	654	11	<5	(5) 4	695	46%	479	22%	934	40	61	(5)	--	52	--
																(20)	--	71	--
																(30)	--	89	--

Source: Plummer 1981.

[1]TDS = Total Dissolved Solids (mg/l)

[2]TC/TA = Total Cations or Total Anions (mg/l as $CaCO_3$)

[3]Cond. = Electrical Conductivity (mmhos/cm)

[4]Test Performed on Filtered Samples

[5]Test Performed with Nitrogenous Demand Suppressed

TABLE 1-12

RANGE OF CONCENTRATIONS IN
ETSI SIMULATION TEST SLURRY FILTRATES

Parameter	Range of Values[a] Measured
Cations (mg/l as $CaCO_3$)	
Sodium	100 - 390
Potassium	10 - 25
Calcium	70 - 570
Magnesium	45 - 330
TOTAL	425 - 1000
Anions (mg/l as $CaCO_3$)	
Chloride	2 - 45
Sulfate	250 - 800
Bicarbonate	90 - 250
TOTAL	425 - 1000
TDS (mg/l)	600 - 1500
pH	6.0 - 8.0
TOC (mg/l)	25 - 129
BOD_5 (mg/l)	19 - 165
COD (mg/l)	50 - 275
Significant Metals	
Copper (µg/l)	<3 - 91
Nickel (µg/l)	<1 - 110
Zinc (µg/l)	<1 - 160
Manganese (µg/l)	<2 - 230
Iron (µg/l)	<2 - 300

Source: Plummer 1981.

[a]For the ranges shown, the maximum value reflects the sum of the highest concentrations of constituents in the carrier water and the maximum leachate concentrations.

conditions has been made. The typical wastewater quality ranges have been determined and are shown in Table 1-13.

An investigation has also been performed in which the extreme wastewater quality conditions were determined. These conditions are estimated to occur only a small percentage of the time and represent the "worst-case" concentrations. The worst case is determined by combining the highest concentration of coal leachate from all the simulation runs with the highest measured and projected concentrations of constituents found in the individual water sources. The values for the extreme conditions are also presented in Table 1-13.

Chemical analyses (PJB Laboratories 1980) for the 129 specified (U.S. EPA) priority pollutants have been carried out (for Bechtel Inc.) on the filtrate resulting from separate slurry simulation tests (Table 1-14). These included the simulated transport and dewatering of a Jacobs Ranch coal sample with a Madison aquifer ground-water sample, and the Jacobs Ranch coal sample with an Oahe Reservoir surface-water sample. All priority pollutant analysis procedures were in conformance with EPA Guidelines Establishing Test Procedures for the Analysis of Pollutants (Federal Register 1979a).

None of the 114 organic priority pollutants were detected in the simulation tests, with the exception of methylene chloride and Bis (2-Ethylhexyl phalate). It is likely that the presence of methylene chloride is due to unavoidable sampling and analytical contamination during standard testing (U.S. EPA 1979a and 1981). The presence of Bis (2-Ethylhexyl pholate) may also be due to unavoidable sampling contamination (U.S. EPA 1981). Several trace metals were reported at low concentrations, as shown in Table 1-14.

Analyses for trace metals were also performed on an ash sample of the Jacobs Ranch coal sample used in simulator runs (Commercial Testing and Engineering Co. 1980). A comparison of these results with the range in concentrations reported by the USGS (Carey 1980) and Drevers et al. (1977) for Wyodak seam coal in Campbell County (Tables 1-6 and 1-7) shows that the metal concentrations in the coal sample used in the simulation runs were approximately equal to or less than the reported literature values, with the exception of the

TABLE 1-13

ESTIMATED DEWATERING PLANT EFFLUENT WATER QUALITY
UNDER VARYING PROJECT CONDITIONS

	Constituent	Initial Concentration (mg/l)[a]	Concentration After 50 Years (mg/l)
Typical Conditions	TDS	900 - 1300	960 - 1310
	SO_4	425 - 750	467 - 757
	Cl	50 - 70	50 - 70
	BOD_5	125 - 175	125 - 175
Extreme Conditions[b]	TDS	1500 - 1900	1560 - 1910
	SO_4	750 - 1075	792 - 1082
	Cl	50 - 70	50 - 70
	BOD_5	125 - 175	125 - 175

Source: Plummer 1980b.

[a] A function of well field water quality, quantity of leached constituents, and coal processing procedures (e.g., source mine, coal storage conditions, and storage duration).

[b] Worst-case estimates, occurring a minimum percentage of the time.

TABLE 1-14

EPA PRIORITY POLLUTANTS MEASURED
DURING ETSI SIMULATION STUDIES

Parameter	Observed Range[a] (µg/l)	Values Outside Range[b] (µg/l)
Arsenic (As)	<2 - <12	
Beryllium (Be)	1 - 2	
Cadmium (Cd)	<4 - <10	
Chromium (Cr)	3 - 27	
Copper (Cu)	20 - 90	
Cyanide (Cn)	<20	
Gold (Au)	<2	
Lead (Pb)	<1 - 17	130
Mercury (Hg)	<2 - <6	27, 28
Molybdenum (Mb)	14	
Nickel (Ni)	<2 - 25	110
Selenium (Se)	<1 - <20	
Silver (Ag)	<3 - <10	
Thallium (Th)	<1 - 5	
Tin (Sn)	<8 - <10	
Zinc (Zn)	10 - 50	160
Bis(2-Ethylhexyl) phthalate	<5	40, 12
Methylene Chloride	<5	17

Source: Plummer 1981.

[a]Range of concentrations measured in ETSI coal slurry simulation tests using several coal and water sources.

[b]Concentrations measured in ETSI coal slurry simulation tests which have been shown statistically to lie outside the expected range of concentrations.

following elements, which were present at higher concentrations in the simulation sample: arsenic (25 ppm), copper (910 ppm), nickel (110 ppm), tin (11 ppm), zinc (390 ppm), uranium (9 ppm), and lead (70 ppm).

A single simulation test has been performed for Bechtel Inc. by LFE (1980) to measure the radioactivity in a slurry prepared from Madison ground water and a Jacobs Ranch coal sample. Based upon this limited data set, the resulting level of radium 226 and was 0.63 picocurie per liter (pCi/l) in the slurry filtrate, with gross alpha 16 pCi/l and gross beta 34±6 pCi/l.

1.F STATE STANDARDS

In compliance with the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500, 86 Stat. 816, 33 USC 1151), Oklahoma, Arkansas, and Louisiana have promulgated water quality standards for surface waters within each state. These standards are designed to enhance the present, future, and potential beneficial uses of particular waterways, and include both numerical and nonnumerical criteria for maintenance of the physical and chemical quality of surface waters. Table 1-15 presents a summary of the designated beneficial uses, and applicable standards, for the specific reaches of rivers proposed as alternative discharge sites. Based upon varying natural background conditions, these site-specific standards vary widely with regard to mineral quality criteria (total dissolved solids, sulfate, and chloride), vary somewhat for toxicity (96-hour median tolerance limit) and radioactivity (Ra 226 and Ra 228), and are identical or similar for criteria such as dissolved oxygen, pH, and turbidity.

In Oklahoma the numerical criteria apply to all flow conditions greater than the 7-day, 2-year low flow. In Arkansas, the criteria apply to one-fourth of all streamflows greater than the 7-day, 10-year low flow. In Louisiana, the criteria apply to all flow conditions.

State standards have also been established for several trace metals and organics, to protect rivers and streams which may be used as primary drinking water sources. These standards are presented in Table 1-16. Staff members of

TABLE 1-15

BENEFICIAL USES AND STATE STANDARDS AT EFFLUENT DISCHARGE LOCATIONS

Delivery Terminal	Receiving-Water Beneficial Uses	Receiving-Water Standards							
		TDS (mg/l)	SO_4 (mg/l)	Cl (mg/l)	DO (mg/l)	96-Hr TLM[a] (percent)	Radium (picocuries/ liter)	pH	Turbidity (JTU)
Ponca City (Oklahoma)	B, C, D, F, G, H, J	1497[b]	193[b]	486[b]	5	5	5[c]	6.5-8.5	50
Pryor (Oklahoma)	A, C, D, E, F, G, H, J	190[b]	49[b]	23[b]	5	5	5[c]	6.5-8.5	50
Oologah (Oklahoma)	A, C, D, E, F, G, H, I, J	475[b]	167[b]	82[b]	5	5	5[c]	6.5-8.5	50
Muskogee (Oklahoma)	B, C, D, E, F, G, H, I, J	1487[b]	139[b]	665[b]	5	5	5[c]	6.5-8.5	50
Independence (Arkansas)	A, C, H	430	60	20	5	1	3[d]	6.0-9.0	50
White Bluff (Arkansas)	A, C, H	750	100	250	5	1	3[d]	6.0-9.0	50
Cypress Bend (Arkansas)	A, C, H	425	150	60	5	1	3[d]	6.0-9.0	50
New Roads (Louisiana)	A, C, H	400	120	75	5	10	-	6.5-9.0	-
Baton Rouge (Louisiana)	A, C, H	400	120	75	5	10	-	6.5-9.0	-
Lake Charles (Louisiana)	C, G, H	225	35	62	4	10	-	6.0-8.5	-

TABLE 1-15 Concluded

Delivery Terminal	Receiving-Water Beneficial Uses	Receiving-Water Standards							
		TDS (mg/l)	SO_4 (mg/l)	Cl (mg/l)	DO (mg/l)	96-Hr TLM[a] (percent)	Radium (picocuries/ liter)	pH	Turbidity (JTU)
Boyce (Louisiana)	A, C, H	780	112	184	5	10	-	6.0-8.5	-
Wilton (Louisiana)	A, C, H	400	120	75	5	10	-	6.5-9.0	-

Note: In Oklahoma the criteria apply to all flow conditions greater than the 7-day, 2-year flow. In Arkansas, the criteria apply to all stream flows greater than the 7-day, 10-year low flow. In Louisiana, the criteria apply to all flow conditions.

[a] Refers to the 96-hour TLM (median tolerance limit) for persistent toxicants; permissible concentrations in the receiving water after mixing are given as percentages of the 96-hour TLM concentrations.

[b] Refers to the sample standard.

[c] Refers to the permissible level of radium 226 plus radium 228.

[d] Refers to the permissible level of radium 226.

Abbreviations:

A = public and private water supply
B = emergency water supply
C = fish and wildlife propagation
D = agriculture
E = hydroelectric power generation
F = industrial and municipal cooling water
G = primary body contact recreation (e.g., swimming)
H = secondary body contact recreation (e.g., boating)
I = navigation
J = aesthetics
K = smallmouth bass fisheries
L = trout fisheries
mg/l = milligrams per liter
TDS = total dissolved solids
SO_4 = sulfate
Cl = chloride
DO = dissolved oxygen
TLM = mean tolerance limit
JTU = Jackson turbidity unit

TABLE 1-16

STATE RECEIVING WATER STANDARDS FOR
HEAVY METALS AND ORGANICS

Parameters	Instream Standards		
	Arkansas[a]	Oklahoma[b]	Louisiana[c]
Arsenic (mg/l)	0.050	0.050	0.050
Barium (mg/l)	5.000	1.000	1.000
Boron (mg/l)	1.000	-	-
Cadmium (mg/l)	0.020	0.010	0.010
Chromium (mg/l)	0.500	0.050	0.050
Copper (mg/l)	0.200	1.000	1.000
Lead (mg/l)	0.100	0.050	0.050
Manganese (mg/l)	1.000	-	-
Mercury (mg/l)	0.005	0.002	0.002
Nickel	0.800	-	-
Selenium (mg/l)	0.020	0.010	0.010
Silver (mg/l)	0.100	0.050	0.050
Zinc (mg/l)	0.500	5.000	5.000
Cyanide (mg/l)	0.050	0.200	0.200
Polychlorinated Biphenyls (µg/l)	-	0.300	-
DDT (µg/l)	-	0.200	-
Aldrin (µg/l)	-	1.000	-
Dieldrin (µg/l)	-	1.000	-
Endrin (µg/l)	-	1.000	0.200
Benzidine (µg/l)	-	1.000	-
Toxaphene (µg/l)	-	1.000	5.000
Phthalate Esters (µg/l)	-	3.000	-
Methoxychlor (µg/l)	-	-	100.00
2,4-D (µg/l)	-	100.00	100.00

[a]Because at least a ten-fold dilution is available at the proposed discharge locations, these maximum limits would apply.

[b]Limits for metals apply to the stream at the point of intake of water supply.

[c]Based on EPA National Interim Primary Drinking Water Standards.

the Louisiana Department of Natural Resources have indicated that revised standards currently being developed will include numerical instream limits for some of the priority pollutants; these will probably be the organic substances specified in the Oklahoma standards (Plummer 1981).

In order to evaluate the effect of the slurry effluent discharge upon receiving-water quality, and its relationship to existing state standards, low flow conditions for receiving streams were determined.

Table 1-17 presents the design low flow, and stream water quality during the design low flow, for the 12 discharge sites. A mass balance was calculated to determine the maximum concentrations of total dissolved solids (TDS), chlorides (Cl) and sulfates (SO_4) which could be tolerated in the dewatering plant discharge without violating stream standards. The mass balance was based on the design low flow conditions (Table 1-17), the maximum concentrations specified by state standards (Table 1-15), and expected dewatering plant effluent discharges (Table 1-2). The calculated allowable constituent concentrations, so determined, are shown in Table 1-18.

The projected range of TDS, Cl, and SO_4 concentrations in the dewatering plant effluent, as shown in Table 1-13, have then been compared to the allowable levels of discharge, to determine the level of treatment necessary to meet existing state stream standards. Tables 1-19, 1-20, and 1-21 present these treatment levels for TDS, SO_4, and Cl. Section 1.H of this report describes proposed treatment facilities that would be necessary to reduce mineral concentrations to acceptable levels.

Water quality simulation tests for radioactivity were also performed using a Madison groundwater source slurried with a proposed project coal source. Table 1-22 summarizes these results and also indicates applicable state effluent limitations and stream standards. Based upon these results, no reduction in radioactivity would be required to meet existing standards. Simulation tests indicated that dewatering plant effluent would generate a biochemical oxygen demand (BOD_5) of 125 to 175 mg/l. At this level, receiving water standards for dissolved oxygen could be exceeded. Section 1.H of this report describes

TABLE 1-17

BACKGROUND FLOW AND WATER QUALITY AT DISCHARGE LOCATIONS DURING LOW FLOW CONDITIONS

Site	Design Low Flow (cfs)	Background Stream Quality at Design Low Flow (mg/l)		
		TDS	Cl	SO_4
Ponca City	598	902	354	113
Pryor	151	154	18	34
Oologah	1.36	225	35	35
Muskogee	2,270	850	363	92
Independence	264	196	8	14
White Bluff	750	549	242	76
Cypress Bend	28,750	239	25	66
New Roads	100,000	259	26	63
Baton Rouge	100,000	280	35	65
Lake Charles[a]	204	1,798	642	101
Boyce	1,650	716	210	136
Wilton	100,000	286	30	60

Source: Plummer, 1981.

[a]Above salt water barrier.

TABLE 1-18

ESTIMATED ALLOWABLE DISCHARGE QUALITY

Site	Dewatering Discharge (cfs)[a]	Alternative[b]	Allowable Discharge Quality (mg/l) TDS	Cl	SO_4
Ponca City	5.4	PA	>10,000	>10,000	9,052
Pryor	4.3	MA, BA	1,454	199	576
Pryor	2.4	PA	2,455	338	993
Oologah	2.8	MA, BA	596	105	231
Muskogee	4.1	PA	>10,000	>10,000	>10,000
Independence	4.1	PA, MA, BA	>10,000	793	3,022
White Bluff	4.1	PA, MA, BA	>10,000	1,713	4,490
Cypress Bend	15.1	BA	>10,000	>10,000	>10,000
New Roads	1.6	PA, MA	>10,000	>10,000	>10,000
Baton Rouge	4.7	MA	>10,000	>10,000	>10,000
Lake Charles[c]	3.3	PA, MA	225	62	35
Boyce	1.5	PA, MA	>10,000	184	112
Wilton	4.1	PA, MA	>10,000	>10,000	>10,000

Source: Plummer 1981.

[a]Maximum instantaneous discharge. Average annual discharge would be slightly less due to system downtime and other factors.

[b]Alternatives: PA = proposed action, MA = market alternative, BA = barge alternative.

[c]Above salt water barrier.

TABLE 1-19

PRELIMINARY ASSESSMENT OF TREATMENT REQUIREMENTS (% TDS Removal)

Carrier Water[a]	Oahe Reservoir / Niobrara County Well Field			Crook County Well Field
	Concentration in Dewatering Plant Effluent (mg/l)			
	800	1000	1200	1500
Discharge Site				
Ponca City	None	None	None	None
Pryor[b]	None	None	None	3%
Oologah	26%	40%	50%	60%
Muskogee	None	None	None	None
Independence	None	None	None	None
White Bluff	None	None	None	None
Cypress Bend	None	None	None	None
New Roads	None	None	None	None
Baton Rouge	None	None	None	None
Lake Charles[c]	72%	78%	81%	85%
Lake Charles[d]	None	None	None	None
Boyce	None	None	None	None
Wilton	None	None	None	None

Source: Plummer 1981.

[a]The concentration in each of the carrier waters is estimated to range in value due to variable source water quality and variable leaching characteristics. This range is indicated by the "Concentration in Dewatering Plant Effluent" headings beneath each of the bars.

[b]Applies to highest proposed discharge of 4.3 cfs.

[c]Above salt water barrier.

[d]Below salt water barrier.

TABLE 1-20

PRELIMINARY ASSESSMENT OF TREATMENT REQUIREMENTS (% SO_4 Removal)

Carrier Water[a]	Oahe Reservoir Niobrara County Well Field		Crook County Well Field	
	Concentration in Dewatering Plant Effluent (mg/l)			
	400	500	1000	1200
Discharge Site				
Ponca City	None	None	None	None
Pryor[b]	None	None	42%	52%
Pryor[c]	None	None	None	17%
Oologah	42%	54%	77%	81%
Muskogee	None	None	None	None
Independence	None	None	None	None
White Bluff	None	None	None	None
Cypress Bend	None	None	None	None
New Roads	None	None	None	None
Baton Rouge	None	None	None	None
Lake Charles[d]	91%	94%	97%	97%
Lake Charles[e]	None	None	None	None
Boyce	72%	78%	89%	91%
Wilton	None	None	None	None

Source: Plummer 1981.

[a]The concentration in each of the carrier waters is estimated to range in value due to variable source water quality and variable leaching characteristics. This range is indicated by the "Concentration in Dewatering Plant Effluent" headings beneath each of the bars.

[b]Applies to highest proposed discharge of 4.3 cfs.

[c]Applies to discharge of 2.4 cfs.

[d]Above salt water barrier.

[e]Below salt water barrier.

TABLE 1-21

PRELIMINARY ASSESSMENT OF TREATMENT REQUIREMENTS (% Chloride Removal)

Carrier Water[a]	Oahe Reservoir / Niobrara County Well Field / Crook County Well Field				
	Concentration in Dewatering Plant Effluent (mg/l)				
	40	50	60	70	100
Discharge Site					
Ponca City	None	None	None	None	None
Pryor[b]	None	None	None	None	None
Oologah	None	None	None	None	None
Muskogee	None	None	None	None	None
Independence	None	None	None	None	None
White Bluff	None	None	None	None	None
Cypress Bend	None	None	None	None	None
New Roads	None	None	None	None	None
Baton Rouge	None	None	None	None	None
Lake Charles[c]	None	None	None	11%	38%
Lake Charles[d]	None	None	None	None	None
Boyce	None	None	None	None	None
Wilton	None	None	None	None	None

Source: Plummer 1981.

[a]The concentration in each of the carrier waters is estimated to range in value due to variable source water quality and variable leaching characteristics. This range is indicated by the "Concentration in Dewatering Plant Effluent" headings beneath each of the bars.

[b]Applies to proposed discharge of 4.3 or 2.4 cfs.

[c]Above salt water barrier.

[d]Below salt water barrier.

TABLE 1-22

RADIOACTIVITY LEVELS MEASURED IN ETSI SIMULATION STUDIES AND STATE EFFLUENT LIMITATIONS

Radioactivity Measured in Slurry Filtrate (pCi/l)		Effluent Limitations		Stream Standards	
		Arkansas (pCi/l)	Oklahoma (pCi/l)	Arkansas (pCi/l)	Oklahoma (pCi/l)
Gross Alpha	16				15
Gross Beta	34 ± 6			1000	50
Radium 226	0.63	30	10	3	5(Ra-226 + Ra-228)

Source: Simulation studies performed by LFE Environmental Analysis Laboratories for Bechtel in November and December 1979, reported January 1980.

proposed treatment facilities which would be necessary to reduce BOD_5 levels in dewatering plant effluent to acceptable levels.

1.G FEDERAL STANDARDS

Discharge of pollutants from point sources and related activities into waters of the United States is regulated under the Federal Water Pollution Control Act Amendments of 1972 and subsequent amendments. Under Section 402 of this act, a permit for discharge may be issued in accordance with the National Pollutant Discharge Elimination System (NPDES). Discharge without a permit is unlawful (Federal Register, June 7, 1979). Authority to issue NPDES permits has not been transferred to the states of Oklahoma, Arkansas, or Louisiana. Therefore, NPDES permits would be issued by U.S. EPA Region VI, subsequent to certification by each state that applicable state receiving water standards had been met.

Under Section 301 of the act, the effluent limitations for categories and classes of point sources, other than publicly owned treatment works, shall require application of the "best available technology economically achievable" for such category. To date, national standards of performance (Section 301) for the control of coal slurry effluent discharge, reflecting best available technology, have not been promulgated. Such standards may be enacted at some future date (Telliard 1979).

Under Section 304 of the act, the U.S. EPA is required to publish and periodically update water quality criteria. Subsequent to the Consent Decree in Natural Resources Defense Council et al. versus Train, the EPA must publish criteria for a list of 65 specified toxic pollutants (Federal Register, March 15, 1979). While these Section 304 criteria are not in themselves enforceable as a water quality standard, they can be used to implement standards under different sections of the act. For example, Section 307 requires the establishment of effluent standards (or prohibitions) for toxic pollutants or combinations of such

pollutants, taking into account the toxicity, persistence, and degradability of the pollutant.

Criteria have been published for review and public comment for the list of 65 toxic pollutants (Federal Register March 15, 1979, July 25, 1979; and October 1, 1979). Recently the final criteria were published by the U.S. EPA (Federal Register, November 28, 1980).

For some of the identified toxic pollutants, Section 304 criteria have been established for the protection of freshwater and saltwater aquatic life, including a numerical maximum value (i.e., not to be exceeded at any time) and a 24-hour average value. Numerical criteria for some of the toxic pollutants have also been established for the protection of human health. At this time, these Section 304 criteria are not enforceable as receiving water standards (Federal Register, November 28, 1980). The EPA will assist states in identifying specific pollutants required for possible inclusion in existing state water quality standards. For these pollutants, the states will have the option of adopting the Section 304 criteria or adjusting the Section 304 criteria based on site-specific analyses.

Several factors are likely to be considered in establishing standards. These could include the technological and economic capacity to control the pollutant discharge; the toxicity, frequency, and concentration of discharge; and the breadth of the data base used to develop the Section 304 criteria (Federal Register, November 28, 1980). The final Section 304 criteria include maximum and average values to protect human health. These concentrations were not developed to serve as "end of the tap" drinking water standards; they do not consider water treatment technology, costs, and other feasibility factors; and they have no regulatory significance under the Safe Drinking Water Act (SDWA) (Federal Register, November 28, 1980).

The National Interim Primary Drinking Water Standards, which are enforceable, control the permissible quality in finished drinking water. These standards differ, for certain constituents, from the Section 304 criteria to protect human health. The states have the option to use the Section 304 criteria to supplement or modify existing SDWA standards in the future, if resulting

standards are not less stringent than SDWA limits, considering factors such as exposure and water treatment technology, costs, and feasibility.

In addition to toxic pollutants, the U.S. EPA has published proposed regulations for a list of 299 "hazardous" substances, under Section 311 of the Act. These include the levels of reportable quantities for accidental discharge. Continuous discharges would be regulated under the NPDES permit requirements of Section 402 and would be exempt from these criteria. (Federal Register, February 16, 1979). Spill situations, however, would be regulated under Section 311, regardless of whether they occur at a facility with an NPDES permit or not (Federal Register, August 29, 1979).

Proposed regulations to govern Spill Prevention Control and Countermeasure (SPCC) plans are still in the draft stage (Federal Register, Sept. 1, 1978). SPCC requirements would only apply to non-transportation related facilities. Thus, spills from a pipeline source would not fall under these proposed regulations; however, spills from holding or process tanks would be subject to regulations governing spills of hazardous substances (Heare 1980).

Under Section 208, regional agencies have been established to develop and implement 208 Water Quality Management Plans. A list of the applicable agencies responsible for 208 planning in the areas in which dewatering plants would be located are shown in Table 1-23. These agencies would be informed of the proposed discharge locations and amounts. Applicable portions of approved 208 Water Quality Management Plans would be examined to assess compliance requirements; state and federal regulatory agencies would also consider the 208 plans, particularly any waste allocation studies, during the NPDES permit process (Plummer 1981).

1.H. TREATMENT FACILITIES

As discussed in Section 1.F, treatment would be required to reduce the levels of TDS, SO_4, Cl, and BOD_5 in the dewatering plant effluent to acceptable levels. Treatment facilities are presently being designed (Plummer 1981). Final

TABLE 1-23

LIST OF 208 WATER QUALITY
MANAGEMENT PLANNING AGENCIES

Coal Delivery Site	208 Planning Agency
Oklahoma	
Oologah	Indian Nations Council of Governments, Oklahoma Department of Pollution Control
Pryor	Oklahoma Department of Pollution Control
Ponca City	Oklahoma Department of Pollution Control
Muskogee	Oklahoma Department of Pollution Control
Arkansas	
Independence	Arkansas Department of Pollution Control and Ecology
White Bluff	Southeast Arkansas Regional Planning Commission
Cypress Bend	Arkansas Department of Pollution Control and Ecology
Louisiana	
Boyce	Louisiana Department of Natural Resources, Division of Water Pollution Control
New Roads	Louisiana Department of Natural Resources, Division of Water Pollution Control
Baton Rouge	Louisiana Department of Natural Resources, Division of Water Pollution Control
Wilton	Louisiana Department of Natural Resources, Division of Water Pollution Control
Lake Charles	Louisiana Department of Natural Resources, Division of Water Pollution Control

Source: Plummer 1981.

plans and specifications would be provided in accordance with state and federal permit application requirements and reviewed by the regulatory agencies as required. Secondary treatment facilities to reduce BOD_5 would be constructed at each dewatering plant site. Two candidate processes are under study at this time: activated sludge and aeration lagoons. In the activated sludge process, the dewatering plant effluent would be retained in holding tanks which could be mechanically mixed or aerated. Microbiological organisms would metabolize organic material present in the effluent, thus reducing the oxygen demand (BOD_5). The effluent would then be retained in settling tanks (clarifiers) to remove the solid fraction (sludge) from the waste stream. A portion of the sludge ("activated sludge") would be recycled to the mixing tanks to provide an active biological population. Aeration lagoons would also reduce the BOD_5 by microbiological breakdown of organic materials, in this case in shallow basins (lagoons) in which the effluent would be retained. Mechanical aeration could be included to facilitate the process. Both of these processes are widely used in the treatment of municipal wastewater.

At certain discharge locations (e.g., Pryor, Oologah, Lake Charles, and Boyce as shown on Tables 1-19, 1-20, and 1-21) reduction in the level of dissolved minerals would be required. Treatment to reduce the levels of TDS, SO_4, and Cl would follow the biological treatment stage, where necessary.

To reduce the level of these dissolved minerals (TDS, SO_4, and Cl), three candidate treatment processes are under consideration: ion exchange, reverse osmosis, and electrodialysis. Table 1-24 presents an estimate of capital and annual operation and maintenance costs for each of these processes. These processes have been described (Plummer 1981) as follows.

> Ion exchange has been used for many years in various applications including water treatment, boiler feed water polishing, wastewater treatment and many other industrial processes. The use of ion exchange to treat this wastewater stream would be a new application of a proven and reliable technology.
>
> Electrodialysis and reverse osmosis are similar processes in that a separation is made across a permeable or semi-permeable membrane. In electrodialysis, an electrical charge is used to provide the driving force while in reverse osmosis, high pressures are used. These

TABLE 1-24

PRELIMINARY COST ESTIMATES FOR
CONSERVATIVE MATERIALS REMOVAL PROCESSES

Treatment Process[a]	Capital Costs ($1000s)	Annual Operating Costs[b] Per Ton of Coal ($1000s)	Annual Operating Costs[b] Per 1000 Gallons ($)
Ion Exchange	10,000	678	0.72
Reverse Osmosis	3,017	853	0.91
Electrodialysis	3,702	655	0.70
Chemical Precipitation	500	950	1.00

Source: Plummer 1981.

[a]Based on a treatment facility with a capacity to treat 4 cfs (2.58 mgd) of wastewater which would be discharged at the White Bluff site.

[b]Based on continuous treatment of the total flow. Actual conditions may permit treatment on a periodic basis.

processes have also been utilized in industrial applications for water treatment.

In all cases development work would be required to select the particular treatment process to be used. Such factors as resin fouling, resin life, and membrane stability would have to be investigated prior to selection of a removal process. In addition, all three processes produce a waste stream which would require disposal in accordance with the requirements of the U.S. Environmental Protection Agency and the states' regulatory agencies.

One additional process, chemical precipitation using barium is also under investigation for the removal of dissolved sulfate. Its feasibility has not, however, been established.

The analyses which have been performed to determine radioactivity levels in the coal slurry waters have indicated that no reduction of radioactivity is required to satisfy the various states' regulations (Table 1-22). If elevated levels of radioactivity are encountered, the initial approach will be to isolate the source. If the source is groundwater, then an attempt will be made to control the levels of radioactivity by changing the groundwater withdrawal procedures. If it is determined that treatment is required to reduce radioactivity levels there are several available alternatives. Treatment measures which have been successfully used include ion exchange, reverse osmosis, and lime or limesoda softening. Reported removal efficiencies for these processes range from 80 to 90 percent (Plummer 1981).

During the biological treatment process (aeration lagoons or activated sludge) the concentrations of trace metals and other constituents would be reduced, along with the BOD_5. Table 1-25 presents the projected treatment efficiencies for each of these processes, and maximum projected concentrations after treatment for constituents measured in ETSI simulation studies to date. In Table 1-26, these projected concentrations after treatment are compared with existing drinking water standards and EPA water quality criteria for toxic pollutants.

As shown in Table 1-26, the projected quality of the dewatering plant effluent, without dilution, could be treated to meet primary drinking water standards for constituents measured in the slurry simulation tests to date.

TABLE 1-25

PRIORITY POLLUTANTS CONCENTRATIONS MEASURED
DURING ETSI SIMULATION STUDIES AND PROJECTED REDUCTIONS

Parameter	Observed Range[a] (µg/l)	Values Outside Range[b] (µg/l)	Average Removal[c] (%)		Maximum Projected Concentrations After Treatment	
			Aerated Pond	Activated Sludge	Aerated Lagoon (µg/l)	Activated Sludge (µg/l)
Arsenic (As)	<2 - <12		--	<43	--	7
Beryllium (Be)	1 - 2		>50	--	1	--
Cadmium (Cd)	<4 - <10		97	31	<1	7
Chromium (Cr)	<3 - 27		63	45	10	15
Copper (Cu)	20 - 90		49	52	46	43
Cyanide (Cn)	<20		45	18	11	16
Gold (Au)	<2		--	--	--	--
Lead (Pb)	<1 - 17	130	86	49	2	9
Mercury (Hg)	<2 - <6	27,28	>99	30	<1	4
Molybdenum (Mo)	14		--	--	--	--
Nickel (Ni)	<2 - 25	110	17	29	21	18
Selenium (Se)	<1 - <20		<50	0	10	20
Silver (Ag)	<3 - <10		--	31	--	7
Thallium (Th)	<1 - 5		44	38	3	3
Tin (Sn)	<8 - <10		--	--	--	--
Zinc (Zn)	10 - 50	160	55	35	22	33
Bis(2-Ethylhexyl) phthalate	<5	40, 12	70	37	<2	3
Methylene Chloride	<5	17	65	21	<2	4

Source: Plummer 1981.

[a]Shows range of concentrations measured in ETSI coal slurry simulation tests using several coal and water sources.

[b]Concentrations measured in ETSI coal slurry simulation tests which have been shown statistically to lie outside the expected range of concentrations.

[c]Average removal percentages based on EPA Treatability Manual, Vol. I, Treatability Data (EPA 600-8-80-0423).

TABLE 1-26

COMPARISON OF PROJECTED CONCENTRATIONS OF PRIORITY POLLUTANTS, AFTER TREATMENT, WITH EXISTING STANDARDS AND CRITERIA (µg/l)

Parameter	Maximum Projected Concentration after Treatment[a]		Drinking Water Standards[b]	U.S. EPA (1980b) Water Quality Criteria for Toxic Pollutants		
				Freshwater Aquatic Life		
	Aeration Lagoon	Activated Sludge		Maximum	24-Hour Average	Human Health
Arsenic (As)	--	7	50	440	c	d
Beryllium (Be)	1	--	c	c	c	d
Cadmium (Cd)	< 1	7	10	e	f	10
Chromium (Cr)	10	15	50	21	.29	50
Copper (Cu)	46	43	1000	6	5.6	c
Cyanide (Cn)	11	16	200	52	3.5	200
Gold (Au)	--	--	c	c	c	c
Lead (Pb)	2	9	50	h	i	50
Mercury (Hg)	1	4	2	0.0017	0.00057	0.144
Molybdenum (Mo)	--	--	c	c	c	c
Nickel (Ni)	21	18	c	j	k	13.4
Selenium (Se)	10	20	10	260	35	10
Silver (Ag)	--	7	50	c	c	50
Thallium (Th)	3	3	c	c	c	13
Tin (Sn)	--	--	c	c	c	c
Zinc (Zn)	22	33	5000	m	47	c
Bis(2-Ethylhexyl) phthalate	< 2	3	c	c	c	15,000
Methylene Chloride	< 2	4	c	c	c	c

[a] Refer to Table 1-25.

[b] U.S. EPA 1980a; all are primary drinking water standards except for copper and zinc which are secondary drinking water standards.

[c] Numerical criteria for maximum permissible level have not yet been established.

[d] "For the maximum protection of human health from the potential carcinogenic effects due to exposure of [this chemical] through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time" (U.S. EPA 1980b). The water quality criteria include estimated concentrations representing different risk levels to human health, but these are presented for information purposes only and do not represent an EPA judgment on an "acceptable" risk level.

e $e^{(1.05[\ln \text{hardness}] - 3.73)}$

f $e^{(1.05[\ln \text{hardness}] - 8.53)}$

g $e^{(0.94[\ln \text{hardness}] - 1.23)}$

h $e^{(1.22[\ln \text{hardness}] - 0.47)}$

i $e^{(2.35[\ln \text{hardness}] - 9.48)}$

j $e^{(0.76[\ln \text{hardness}] + 4.02)}$

k $e^{(0.76[\ln \text{hardness}] + 1.06)}$

l $e(1.72[\ln \text{hardness}] - 6.52)$

m $e^{(0.83[\ln \text{hardness}] + 1.95)}$

Dilution and dispersion within the receiving waters would reduce these levels further. As discussed in Section 1.G, the U.S. EPA criteria have not yet been promulgated as enforceable standards. They may be used or modified as a basis for future standards. These criteria would likely be implemented as receiving water criteria (Carr 1980) as opposed to point source effluent discharge standards. Because of dilution and dispersion of the dewatering plant effluent at each of the discharge sites, the resultant level in receiving waters would be lower than the maximum projected levels shown in Table 1-26. The absence of sufficient background data for the level of these constituents at each discharge site does not permit a calculation of projected instream levels. However, should the EPA criteria become established as standards, the NPDES permit at each site would require instream monitoring for compliance.

1.I TREATED WASTEWATER ALTERNATIVE

An additional alternative water source has been included as an alternative under consideration. This alternative is described in detail in Chapter 1 of the Final EIS. Basically, it would involve the transport of treated wastewater from 10 locations in South Dakota, to Gillette, Wyoming.

Table 1-27 shows the locations and amounts of treated wastewater readily available by 1985.

To date, simulation studies have not been performed using a proposed coal source combined with a treated wastewater sample. In order to apply for an NPDES discharge permit should this alternative be selected, it would be necessary to conduct additional simulation studies. Water quality parameters to be tested would likely have to include the 129 designated priority pollutants, the same inorganic parameters previously tested for, biochemical oxygen demand, and possibly fecal coliform. Chapters 3 and 4 of the Final EIS describe the existing environmental conditions and potential environmental impacts under this alternative.

TABLE 1-27

LOCATIONS AND AMOUNTS OF WASTEWATER AVAILABLE FOR THE PROPOSED WET SYSTEM

Location	Wastewater (acre-feet/year)
Rapid City	8,512
Ellsworth Air Force Base	1,434
Box Elder	459
Rapid Valley	459
Lead/Deadwood Area	2,577
Homestake	4,032
Whitewood	101
Spearfish	605
Spearfish Area	112
Belle Fourche	975
	19,266

Source: Sixth District Council of Governments 1981

Chapter 2
CONSTRUCTION EFFECTS AT STREAM CROSSINGS

This section addresses the potential surface water quality effects, principally the generation of suspended sediments, which could occur during construction activities at creeks, streams and rivers crossed by the proposed pipeline system.

2.A SUMMARY OF STREAM CROSSINGS

The proposed ETSI Coal Slurry Pipeline System includes three alternative water supply pipeline routes, two slurry gathering line pipeline routes, and four alternative slurry transport pipeline routes. Table 2-1 summarizes the stream crossings for these routes. The construction of the proposed action would require the crossing of 410 intermittent, 127 minor perennial and 28 major perennial creeks, streams and rivers, and 92 bayous in six states. Tables A-1 through A-23 in the Appendix present the names and location of each of these crossings.

2.B POTENTIAL CONSTRUCTION METHODS

The particular type of trench and fill operation at stream crossings would depend upon the crossing width and depth and underlying streambed materials. Intermittent streams would be crossed using spread equipment (backhoe) during periods of low or no flow. In minor perennial streams, half the flow could be temporarily diverted and the pipeline trenched "dry" with the aid of dewatering wells, or draglines could be used from the shore or floating positions. Major perennial streams would be trenched by dredging (bucket or hydraulic cutterhead) or directional drilling (tunneling underneath the riverbed). In bayous or wetlands, backhoes or draglines on movable barges would be used. Table 2-2 shows estimated average trench and fill rates for these types of equipment.

TABLE 2-1

SUMMARY OF STREAM CROSSINGS

Pipeline Route	Number of Stream Crossings			
	Intermittent	Major Perennial	Minor Perennial	Bayou
Alternative Water Supply Lines				
Niobrara County	32	-	-	-
Crook County	19	-	1	-
Oahe Reservoir	138	2	10	-
Slurry Gathering Lines				
North Rawhide	19	-	2	-
North Antelope	10	-	-	-
Alternative Coal Slurry Pipeline				
Proposed Action	347	59	107	84
Market Alternative	364	51	130	84
Barge Alternative	272	25	59	23
Colorado Alternative with Proposed Action	404	57	116	84
with Market or Barge Alternative	363	58	89	84

TABLE 2-2

ESTIMATED DREDGE AND FILL RATES
DURING STREAM CROSSING CONSTRUCTION

Equipment	Capacity (Cu. Yd.)	Rate (Cu. Yd./Hr.)
Backhoe	1-1/2 to 2	150
Backhoe (on Pontoons/Barge)	2 to 2-1/2	100
Dragline	2-1/2	60-80
	2	100
	3	120-150
Dragline (on Barge)	2	250
Dragline (on Marsh Buggy)	2	100
Bucket Dredge	4	320
Hydraulic Dredge (Cutterhead)	20 inch	420
	24 inch	750
	30 inch	1040

Sources: Northam 1980; Pendarius 1980; Williams 1980.

Following construction, the depth of bed scour at crossings would be a function of several site-specific factors, including flow velocity, depth and gradient, and bed material characteristics such as median diameter, and specific weight. It is assumed that stream crossings would be designed to comply with existing regulatory stipulations (e.g. burial 4 feet or 20 percent of scour depth, whichever is greater, beneath the maximum scour depth elevation). The effects of scour upon pipeline integrity have been evaluated separately and this analysis will consider only construction-related turbidity effects.

2.C METHODOLOGY OF ANALYSIS

Background Data

Few published data are available that describe the effects upon receiving water quality associated with stream crossing construction activity (e.g., increases in levels of suspended solids and turbidity). Crabtree et al. (1978) presented the results of pipeline construction monitoring for three small creek crossings in Michigan. The levels of fine suspended sediment (less than 0.063 mm) reached 280 to 4200 mg/l, while coarse solids (greater than 0.063 mm) reached 70 to 450 mg/l, at distances of 30 to 100 feet downstream of trenching operations. Hay (1972) found that suspended sediment levels downstream of stream crossing construction activities in a shallow (18 inches in depth) Michigan trout stream (sand and gravel bed) did not increase by more than 10 mg/l, at distances of 300 feet downstream. Landeen and Brandt (1975) investigated the increases in suspended sediment levels associated with instream pipeline construction (draglines) on two rapidly flowing Alaskan rivers. In the La Biche River, trenching operations were found to generate suspended sediment levels of 100 to 200 mg/l, persisting downstream a distance of 1,300 feet. In the Rotaneelee River, the concentration of suspended sediment reached 52 mg/l at 100 feet downstream of trenching. Samples taken 24 hours after trenching had ceased indicated that less than 10 mg/l of sediments remained in suspension as a result of construction activities.

Field monitoring data is unavailable for similar pipeline stream crossings along the proposed route, based upon data requests from the U.S. Soil Conser-

vation Service, U.S. Geological Survey, U.S. Army Corps of Engineers, and other agencies.

Estimation of Suspended Sediments

A precise estimation of instream construction effects at any particular crossing would require detailed information related to stream bed material characteristics, stream velocity and depth, mass transfer rate, and other factors. Such data are not available for even a small percentage of the proposed or alternative crossings. Therefore expected crossing effects can only be estimated for generic crossing types, each having assumed typical stream characteristics. For the purposes of this evaluation, four crossing types have been evaluated: intermittent creeks, minor and major perennial streams and rivers, and bayou streams or waterways.

Detailed modeling methodologies to address pipeline stream crossing effects are not available in the published literature. A methodology to evaluate dredged material disposal in estuaries and rivers has recently been developed under the U.S. Army Corps of Engineers Dredged Material Transport Program. A complete description of this methodology is contained in the Dredged Material Research Program Technical Report Series (Barnard 1978 and Schubel et al. 1978).

Extensive field monitoring data of turbidity plumes in the vicinity of disposal operations has been applied (Schubel et al. 1978) in the development of a simplified model for prediction of increases in levels of suspended sediments adjacent to dredging disposal operations. With certain qualifying assumptions (which will be discussed in Section 2.D) this model can be adapted to river crossing trenching activities (Carter 1980; Wilson 1980) by the estimation of several input parameters:

Discharge Rate of Material Suspended in a Water Column (q), determined as 0.01 x dredging equipment mass discharge rate (Q), measured in mg/sec.

Sediment Plume Thickness (D), or average thickness of the water containing the plume determined as one-half the average depth of water column in the disposal area, measured in cm.

Horizontal Diffusion Velocity (w), describing the rate of horizontal spread of the plume, which for lakes and rivers, based upon investigations completed by Okubo (1971), is given as 0.5 cm/sec (Wilson 1980).

Particle Settling Velocity (Vs), which is determined from estimated mean particle diameter using Figure 2-1, measured in cm/sec.

Plume Age (t), which is the time required for a particle with a settling velocity (Vs) to settle a specified vertical distance (D) relative to the depth of water, which for the near bottom plume, is given by

$$t = \frac{D}{Vs}$$

and is measured in seconds.

Average current velocity (u), which is the average streamflow velocity, measured in cm/sec.

After determining or estimating these six parameters, two nondimensional ratios are determined, rounded to the nearest tenth:

$$\frac{w}{u}, \quad \text{and}$$

$$\gamma r = \frac{Vs\,(t)}{D}$$

Two scaling factors are also developed:

Distance Scaling Factor (DSF) in cm

$$DSF = ut$$

Concentration Scaling Factor (CSF) in mg/cc

$$CSF = \frac{q}{\pi w^2 Dt}$$

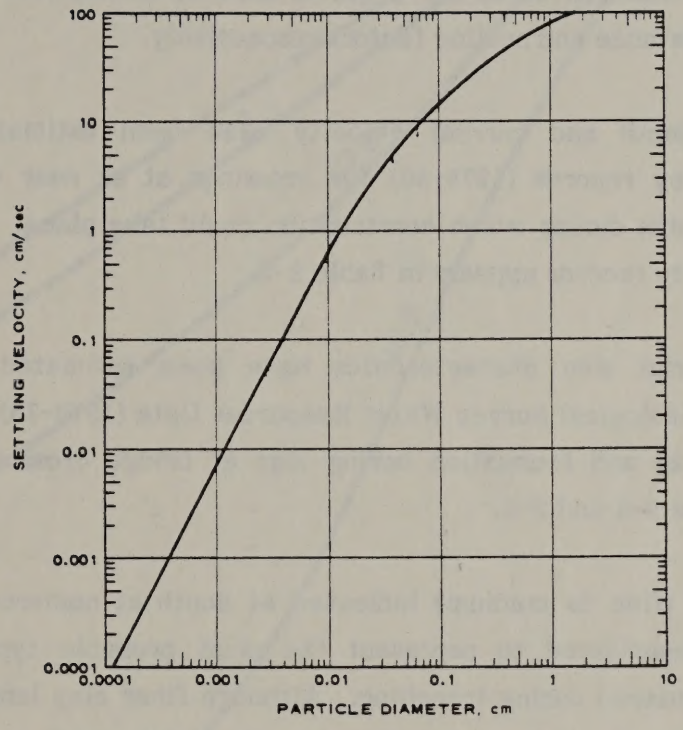

Figure 2-1. SETTLING VELOCITY VERSUS MEAN PARTICLE DIAMETER

These factors can be used to calculate most probable estimates of construction-caused increase in suspended sediments (above background) along the plume center line as a function of distance from the discharge point. This is accomplished by the use of several model nomographs which have been derived from the results of actual field measurements (Figures 2-2 to 2-6) and the scaling factors developed above, which can be rounded to the nearest one tenth (Schubel et al. 1978). The nondimensional variables determined from these nomographs are then converted into physical units of meters and milligrams per liter using the distance and scaling factors respectively.

Average depth and current velocity have been estimated from U.S. Geological Survey records (1979-80) for crossings at or near existing gaging stations for months during which construction could take place. A summary of depth and velocity records appears in Table 2-3.

Bed material size characteristics have been estimated from several sources: U.S. Geological Survey Water Resources Data (1970-78), miscellaneous published records, and foundation boring logs at bridge crossings. This data appears in Tables 2-4 and 2-5.

Silty sand (fine to medium) indicated at depth at numerous streams and waterways, is considered to represent the most probable type of fine bed materials encountered during trenching. Although finer clay lenses are present at depth at some of the crossings, the aggregation of particles would limit the dispersion and transport of clay sediments and thus would not necessarily represent the worst case alteration in downstream receiving water quality.

According to the AASHTO Manual on Foundation Engineering (1967) silty sands may be composed of 20% clay, 40% silt and 40% sand. Based on the standards adopted by the Subcommittee on Sediment Terminology of the American Geophysical Union (Lane 1947) this classification would represent a mean particle diameter of approximately 0.082 mm, which is used for the analysis of typical trenching activities. The specific weight is given (Trask 1931) as 86 lbs per ft^3 (1378 kg/m^3).

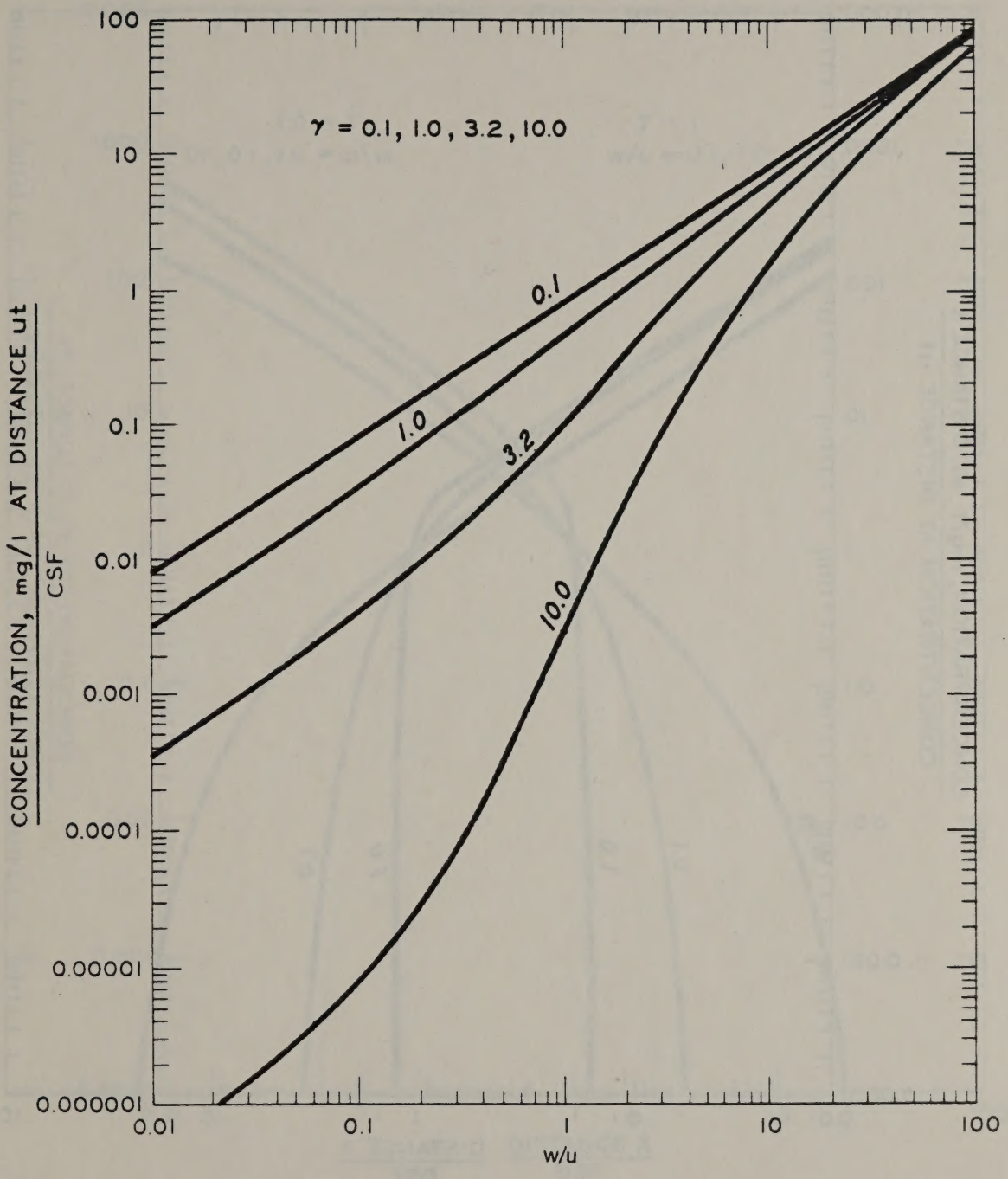

Figure 2-2. RELATIONSHIP BETWEEN w/u AND

$$\frac{\text{SOLIDS CONCENTRATION AT DISTANCE ut}}{\text{CSF}}$$

FOR Υ = 0.1, 1, 3.2, AND 10

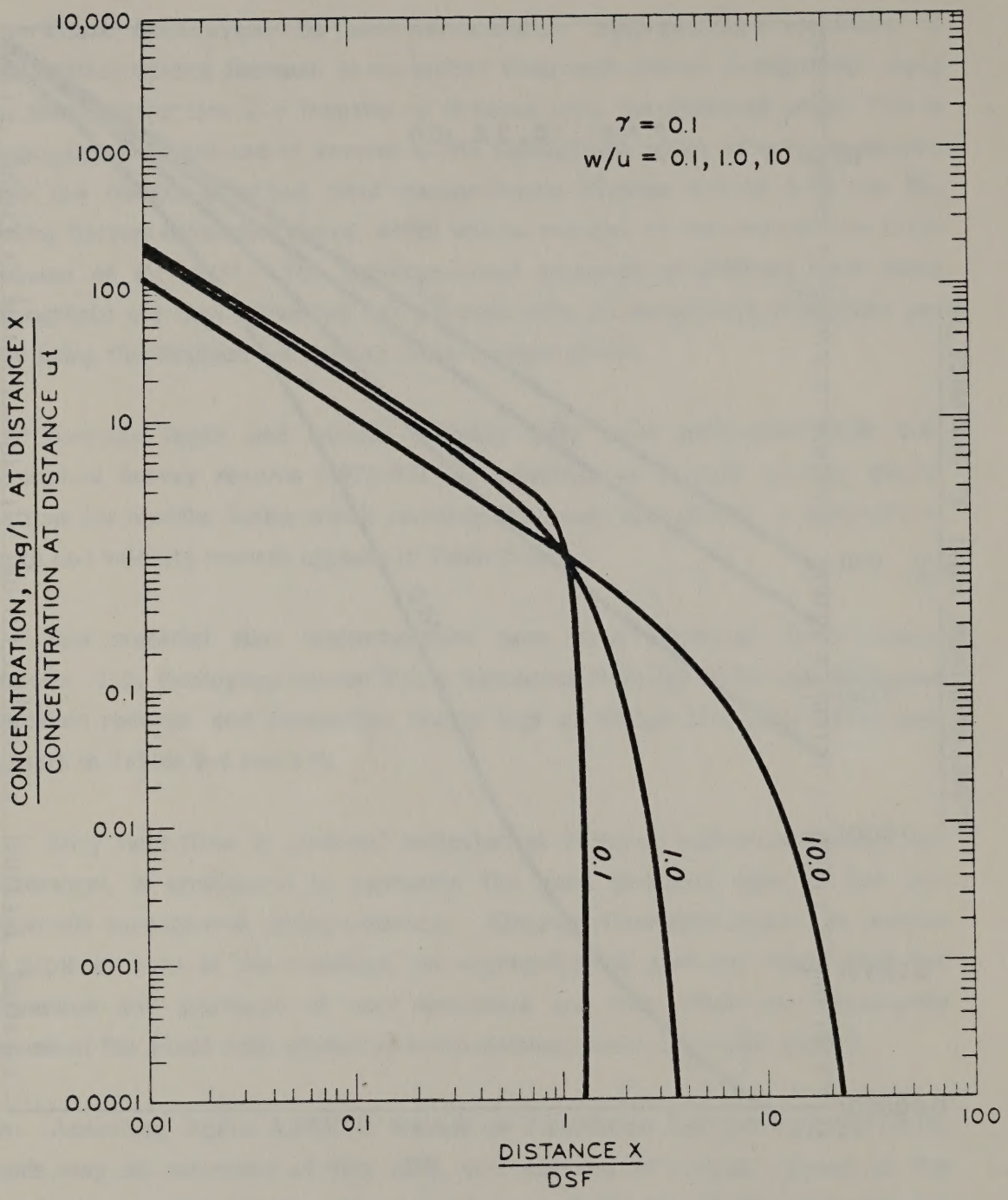

Figure 2-3. RELATIONSHIP BETWEEN $\frac{\text{DISTANCE X}}{\text{DSF}}$ AND $\frac{\text{SOLIDS CONCENTRATION AT DISTANCE X}}{\text{SOLIDS CONCENTRATION AT DISTANCE ut}}$ FOR w/u EQUAL TO 0.1, 1, AND 10 AND $\Upsilon = 0.1$

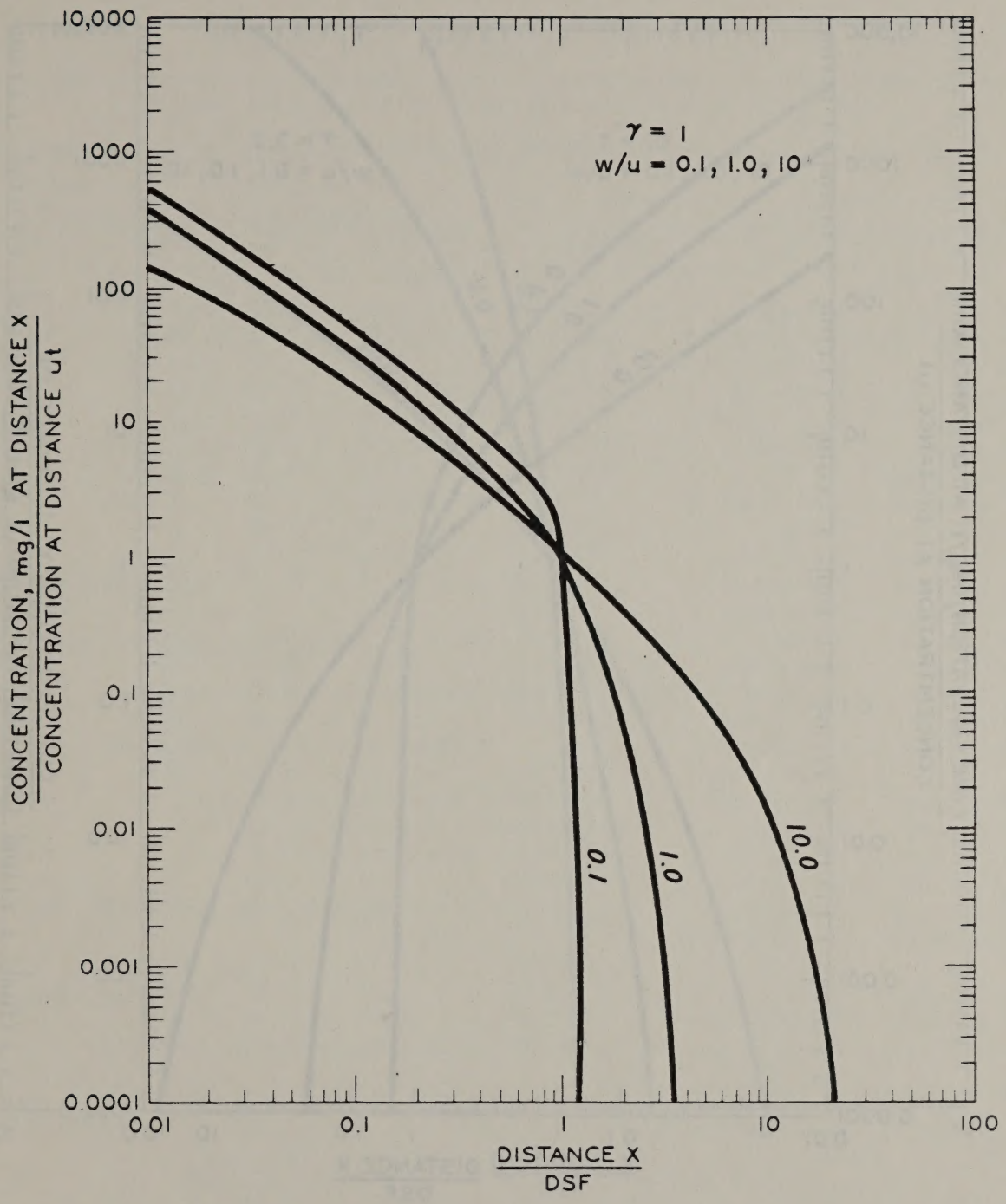

Figure 2-4. RELATIONSHIP BETWEEN $\frac{\text{DISTANCE X}}{\text{DSF}}$ AND $\frac{\text{SOLIDS CONCENTRATION AT DISTANCE X}}{\text{SOLIDS CONCENTRATION AT DISTANCE ut}}$ FOR w/u EQUAL TO 0.1, 1, AND 10 AND $\Upsilon = 1$

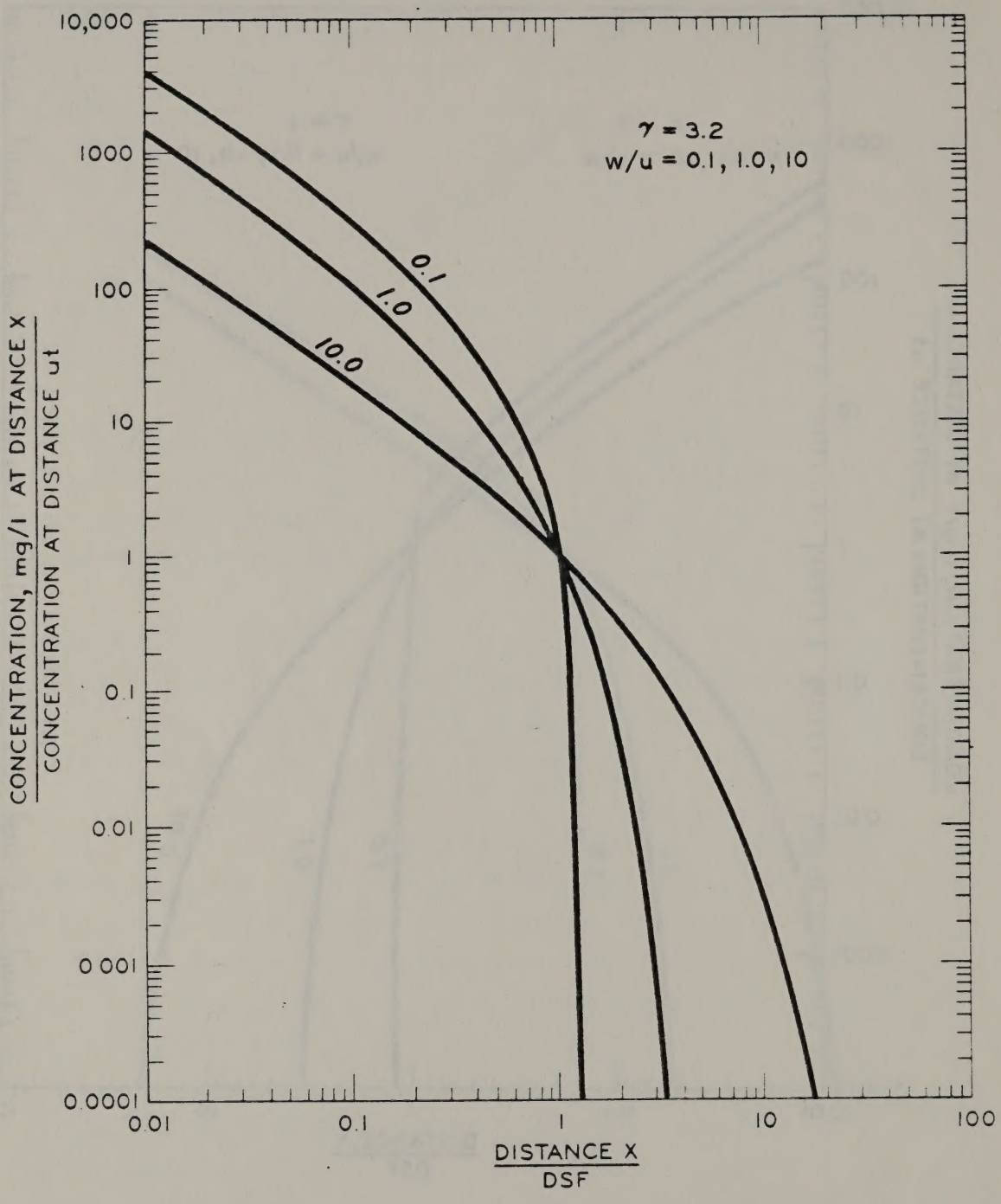

Figure 2-5. RELATIONSHIP BETWEEN $\frac{\text{DISTANCE X}}{\text{DSF}}$ AND $\frac{\text{SOLIDS CONCENTRATION AT DISTANCE X}}{\text{SOLIDS CONCENTRATION AT DISTANCE ut}}$ FOR w/u EQUAL TO 0.1, 1, AND 10 AND $\Upsilon = 3.2$

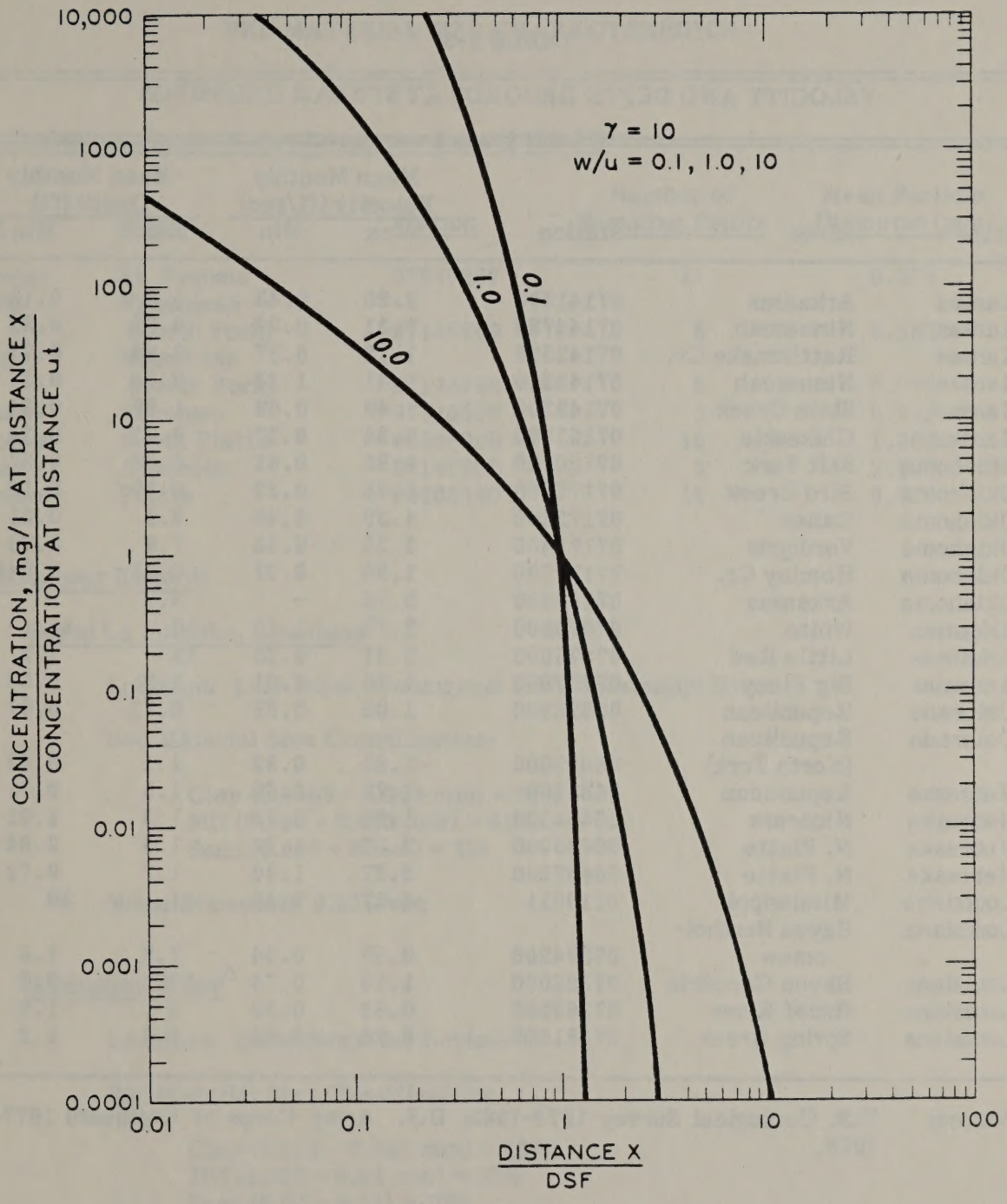

Figure 2-6. RELATIONSHIP BETWEEN $\frac{\text{DISTANCE X}}{\text{DSF}}$ AND $\frac{\text{SOLIDS CONCENTRATION AT DISTANCE X}}{\text{SOLIDS CONCENTRATION AT DISTANCE ut}}$ FOR w/u EQUAL TO 0.1, 1, AND 10 AND $\Upsilon = 10$

TABLE 2-3

VELOCITY AND DEPTH RECORDS AT STREAM CROSSINGS

State	River	Station	Mean Monthly Velocity (ft/sec)		Mean Monthly Depth (ft)	
			Max	Min	Max	Min
Kansas	Arkansas	07141300	2.35	0.43	5.5	0.16
Kansas	Ninnescah	07144780	1.31	0.73	0.62	0.32
Kansas	Rattlesnake Cr.	07142575	1.12	0.57	0.84	0.24
Kansas	Ninnescah	07145200	1.41	1.13	0.74	0.32
Kansas	Slate Creek	07145700	1.49	0.69	1.39	0.24
Kansas	Chikaskia	07151500	1.34	0.37	0.62	0.24
Oklahoma	Salt Fork	07150000	1.95	0.61	0.88	0.37
Oklahoma	Bird Creek	07177500	1.46	0.33	0.59	0.19
Oklahoma	Caney	07175500	4.05	0.46	2.6	0.91
Oklahoma	Verdigris	07171400	3.28	0.33	7.9	0.25
Oklahoma	Hominy Cr.	07177700	1.95	0.27	0.32	0.045
Oklahoma	Arkansas	07152500	3.16	-	8.2	-
Arkansas	White	07074500	2.74	1.10	16	14
Arkansas	Little Red	07076000	2.81	0.25	11	1.1
Arkansas	Big Piney	07257000	1.78	0.91	1.2	0.88
Colorado	Republican	06826500	1.05	0.89	0.72	0.67
Colorado	Republican (North Fork)	06823000	1.60	0.82	1.1	0.49
Nebraska	Republican	0683700	1.77	0.62	1.5	0.71
Nebraska	Niobrara	06454500	1.52	0.75	1.3	1.01
Nebraska	N. Platte	06686000	2.32	1.71	1.3	0.84
Nebraska	N. Platte	06687500	2.27	1.40	1.7	0.72
Louisiana	Mississippi	0110011	4.27	2.46	41	30
Louisiana	Bayou Barthol-omew	07364200	0.93	0.54	7.8	1.6
Louisiana	Bayou Cocodrie	07382000	1.10	0.73	10.4	2.0
Louisiana	Bouef River	07368000	0.62	0.30	3	1.9
Louisiana	Spring Creek	07381800	0.88	0.74	1.4	1.2

Source: U.S. Geological Survey 1979-1980; U.S. Army Corps of Engineers 1977-1979.

TABLE 2-4

BED MATERIAL SIZE CHARACTERISTICS

U.S. Geological Survey Water Resources Data (1970-78)

State	River	Station	Number of Sampling Points	Mean Particle Diameter (mm)
Arkansas	St. Francis	07047907	11	0.376
Kansas	Ninnescah (South Fork)	07145200	6	0.582
Kansas	Ninnescah (North Fork)	07144780	6	0.770
Kansas	Arkansas	07146500	3	0.949
Nebraska	North Platte	06686000	16	1.300
Kansas	Arkansas	07140000	3	2.800
Nebraska	Platte	06805500	18	0.720

Miscellaneous Records

Bayou La Fourche, Louisiana[a]

Location: 12.3 miles downstream from Mississippi River

Bed Material Size Classification:

Clay (0.0005 - 0.004 mm) = 57%
Silt (0.004 - 0.062 mm) = 41%
Sand (0.062 - 2 mm) = 2%

Mean Diameter: 0.035 mm

Mississippi River[b]

Location: Donaldsonville, Louisiana

Bed Material Size Classification:

Clay (0.001 - 0.003 mm) = 45%
Silt (0.003 - 0.04 mm) = 35%
Sand (0.04 - 0.18) = 20%

Mean Diameter: 0.030 mm

Middle Loup River[c]

Location: Nebraska

Mean Diameter: 0.3 - 0.6 mm

TABLE 2-4 Concluded

Little Arkansas River[d]
Location: Kansas
Mean Diameter: 0.5 - 1.1 mm

[a]Doyle 1972.

[b]U.S. Army Corps of Engineers 1975.

[c]Hubbell and Matejka 1959.

[d]Albert and Stramel 1966.

TABLE 2-5

BED MATERIAL CHARACTERISTICS ALONG ALTERNATIVE ROUTES
ASSEMBLED FROM BORING LOGS

State	Route[a]	River	Bed Material Description[b]	Mean Particle Diameter (mm)[c]
Kansas	PA	Chikaskia	(1) sand shale	-
			(2) sandy loam sand shale	
			(3) silty sand sand (fine to medium)	
Kansas	PA	Ninnescah	sandy loam sand & gravel silty clay sand (fine)	-
Kansas	BA	Arkansas	(1) sand (fine)	-
	MA		(2) sand (fine to coarse)	-
Nebraska	MA BA	Sappa Creek	silt shale	-
Nebraska	PA MA BA	Republican	silt clayey silt silty sand sand (fine to coarse) gravel	1.1 to 1.5
Nebraska	PA MA BA	Niobrara	silty sand sand (with gravel)	-
Nebraska	PA MA	North Platte	(1) sand (fine to coarse)	-
	BA		(2) silt sand (fine to medium) gravel	1.5
			(3) sand (fine to coarse) gravel	
Nebraska	PA MA	South Platte	silty sand gravel silt	-

TABLE 2-5 Continued

State	Route[a]	River	Bed Material Description[b]	Mean Particle Diameter (mm)[c]
Colorado	CA	South Platte	(1) sand (fine to medium) gravelly sand	1.30
			(2) sandy clay sand (medium to coarse)	0.32
Colorado	CA	Republican	sand (fine to coarse) clayey sand clay shale	-
Arkansas	PA MA BA	Little Red	sandy clay clay sand	-
Arkansas	PA MA BA	White	sand- sandy clay shale lenses	
Arkansas	PA MA BA	Illinois Bayou	clay sandy clay sandy silt silty sand	-
Arkansas	PA MA BA	Big Piney	sandy clay sand silt	-
Arkansas	PA MA BA	Arkansas	(1) sand (fine) sandy silt clayey silt	-
			(2) silty sand silt sand (fine)	

TABLE 2-5 Continued

State	Route[a]	River	Bed Material Description[b]	Mean Particle Diameter (mm)[c]
Louisiana	PA MA	Mississippi	(1) sand (fine to medium) sandy silt silty clay clayey, silt clay (medium & soft) silty sand clay (brown & grey)	-
			(2) sand silty clay organic (6%)	
Louisiana	PA MA	Atchafalaya	silty sand clay loam silty clay clay	-
Louisiana	PA MA	Calcasieu	(1) silty clay sandy clay clayey sand clayey silt sand silty sand clay iron oxide (trace) organic (3-7%)	-
			(2) sandy clay silty clay clayey sand silty sand sand iron oxide (trace) organic (4-6%)	-
Louisiana	PA MA	Black Bayou	silty clay clayey silt silty sand	-

TABLE 2-5 Concluded

State	Route[a]	River	Bed Material Description[b]	Mean Particle Diameter (mm)[c]
Louisiana	PA MA	Red	(1) silty clay silty sand clayey silt sand (fine) organic (trace)	-
			(2) silty sand silty clay clayey silt silt organic (2%) iron oxide (trace)	
Louisiana	PA MA	Atchafalaya Floodway Basin	sandy silt silty top soil clayey silt silty clay clay (grey) roots & wood particles organic (4-16%)	
Louisiana	PA MA	Little	clayey sand silty sand silty clay shell (trace) sand (fine to medium) clay (grey) organic (trace)	

Sources: Arkansas State Highway and Transportation Dept. 1980; Colorado Division of Highways 1968-1974; Kansas Dept. of Transportation 1980; Louisiana Dept. of Transportation and Development 1980; Nebraska Dept. of Roads 1980.

[a]PA = Proposed Action
MA = Market Alternative
BA = Barge Alternative

[b]Bed materials present in the 0-20 foot range beneath the streambed.

[c]Estimated from sieve analyses.

2.D RESULTS

Increases in suspended solids downstream of stream crossings have been estimated for a major perennial river (Mississippi River), a representative minor perennial stream, and a bayou waterway. Because trenching across intermittent creeks or washes would take place during dry periods, no significant surface water quality effects are anticipated for these crossings. Similarly, directional drilling (beneath the riverbed) would not increase suspended sediment levels in receiving waters.

The levels of suspended sediment that could result from representative construction activities have been estimated using the Dredged Material Research Program. Tables 2-6, 2-7, and 2-8 present these results. It should be noted that the Dredged Material Research Program does have certain limitations. First this program assumes that the dredged materials are discharged from a point source, namely a dredge disposal pipe; and secondly, the program assumes that there are no limits to the lateral spread of the disposed materials.

To consider a point-source discharge the estimates for minor perennial crossings and bayou waterways are made for intermittent trenching operations (backhoe or dragline) at a single point in the streambed. For major perennial crossings, which could include a line source due to hydraulic dredging, estimates have been made for steady-state conditions only, far downstream of construction operations.

At very narrow crossings, the limited lateral spread of turbidity plume due to reflection from stream banks could result in somewhat higher suspended solids levels than those presented in Tables 2-6 to 2-8.

It should also be noted that these estimates have assumed a typical bed material size based on mean particle diameter. A very small fraction of finer materials could travel downstream a greater distance before settling entirely to the stream bottom (assuming no resuspension), where the materials would ultimately continue to travel downstream as bedload. For example, in the minor perennial crossing type, a worst case estimate for transport of a silt fraction

TABLE 2-6

CALCULATION OF ESTIMATED SUSPENDED SEDIMENT INCREASE FOR TRENCHING ACTIVITIES AT MINOR PERENNIAL STREAM CROSSINGS

Trenching Method: Backhoe, 1.5 cu yd capacity.

Trenching Rate: 150 cu yd/hr

Mass Discharge Rate (Q)

$$\frac{150 \text{ cu yd}}{\text{hr}} \times \frac{1 \text{ cycle}}{1.5 \text{ cu yd}} = \frac{100 \text{ cycles}}{\text{hr}} = \frac{36 \text{ sec}}{\text{cycle}}$$

x 50% of cycle within water column,

$$= \frac{18 \text{ sec}}{\text{cycle}}$$

$$\frac{1.5 \text{ cu yd}}{\text{cycle}} \times \frac{1 \text{ cycle}}{18 \text{ sec}} = \frac{0.08 \text{ cu yd}}{\text{sec}}$$

$$Q = \frac{0.08 \text{ cu yd}}{\text{sec}} \times \frac{0.765 \text{ m}^3}{\text{cu yd}}$$

$$\times \frac{1378 \text{ Kg}}{\text{m}^3} = 8.4 \times 10^7 \text{ mg/sec}$$

Suspended Material (q)

$$q = 0.01 (8.4 \times 10^7 \text{ mg/sec}) = 8.4 \times 10^5 \text{ mg/sec}$$

Vertical Thickness (D)

Average Depth = 1.0 ft

$$D = \frac{1}{2} (1 \text{ ft}) \times \frac{30.5 \text{ cm}}{\text{ft}} = 15.3 \text{ cm}$$

Horizontal Diffusion Velocity (w)

Lakes and Rivers = 0.5 cm/sec

Settling Velocity (Vs)

Mean Particle Diameter = 0.082 mm

Vs = 0.3 cm/sec (from Figure 2-1)

TABLE 2-6 Concluded

Age of Plume (t)

$$t = \frac{D}{Vs} = \frac{15.3}{0.3} = 51 \text{ sec}$$

Stream Velocity (u)

Range: 0.25 to 1.95 ft/sec
Use Average: u = 1.1 ft/sec = 33.5 cm/sec

$$CSF = \frac{8.4 \times 10^5}{\pi (.25)(15.3)(51)} = 1.37 \times 10^3 \text{ mg/cc} = 1.37 \times 10^6 \text{ mg/l}$$

$$w/u = \frac{0.5}{33.5} = 0.015$$

$$\gamma = \frac{(0.3)(51)}{15.3} = 1.0$$

Centerline Concentrations

DSF = ut = 33.5 (51) = 1708 cm = 56 ft
At ut, $\frac{C}{CSF}$ = 0.004 (from Figure 2-2)
$C = 0.004(1.37 \times 10^6) = 5500$ mg/l

From Figure 2-4:
At 0.89 ut = 50 Ft
C = 2.5 (5500) = 13,750 mg/l

At 1.1 ut = 60 ft
C = 0.01 (5500) = 55 mg/l

At 1.2 ut = 70 ft
C = 0.0001 (5500) = <1 mg/l

TABLE 2-7

CALCULATION OF ESTIMATED SUSPENDED SEDIMENT INCREASE AT MISSISSIPPI RIVER CROSSING (MAJOR PERENNIAL)

Trenching Method: Hydraulic Dredge (20 inch)

Trenching Rate: 420 cu yd/hr

Mass Discharge Rate (Q)

$$Q = (420 \frac{\text{cu yd}}{\text{hr}}) \times \frac{(1 \text{ hr})}{3600 \text{ sec}} \times \frac{(0.765 \text{ m}^3)}{\text{cu yd}} \times \frac{1378 \text{ kg}}{\text{m3}} = 1.2 \times 10^8 \text{ mg/sec}$$

Suspended Material (q)

$$q = (0.05 \times 1.2 \times 10^8) = 6.0 \times 10^6 \text{ mg/sec}$$

Vertical Thickness (D)

Average Depth = 36 ft

D = (0.5) x (36) = 18 ft = 550 cm

Diffusion Velocity (w)

Lakes and Rivers = 0.5 cm/sec

Settling Velocity (Vs)

Mean Particle Diameter = 0.082 mm

Vs = 0.3 cm/sec

Age of Plume (t)

$$t = \frac{550}{0.3} = 1830 \text{ sec}$$

Stream Velocity (u)

Range: 2.46 to 4.27 ft/sec
Use Average: u = 3.4 ft/sec = 104 cm/sec

TABLE 2-7 Concluded

$$CSF = \frac{6.0 \times 10^6}{\pi (0.25)(550)(1830)} = 7590 \text{ mg/l}$$

$$w/u = \frac{0.5}{104} = 0.005$$

$$\gamma = \frac{(0.3) \times (1830)}{550} = 1.0$$

Centerline Concentration

At ut = 104 (1830) = 1.9×10^5 cm = 6240 ft
C = 0.003 (7590) = 22.8 mg/l

At 0.96 ut = 6000 ft
C = 2 (22.8) = 46 mg/l

At 0.8 ut = 5000 ft
C = 3.5 (22.8) = 80 mg/l

At 0.4 ut = 2500 ft
C = 10 (22.8) = 228 mg/l

At 0.16 ut = 1000 ft
C = 32 (22.8) = 730 mg/l

At 0.08 ut = 500 ft
C = 80 (22.8) = 1800 mg/l

At 1.2 ut = 7500 ft
C = 0.0001 (22.8) = < 1 mg/l

TABLE 2-8

CALCULATION OF ESTIMATED SUSPENDED SEDIMENT INCREASE AT WETLAND/BAYOU CROSSING

Trenching Method: Backhoe (2 cu yd) on Mats

Trenching Rate: 100 cu yd/hr

Mass Discharge Rate (Q)

$$\frac{(100 \text{ cu yd})}{\text{hr}} \times \frac{(1 \text{ cycle})}{2 \text{ cu yd}} = \frac{50 \text{ cycles}}{\text{hr}} = \frac{72 \text{ sec}}{\text{cycle}}$$

x 50% of cycle within water column,

$$= \frac{36 \text{ sec}}{\text{cycle}}$$

$$\frac{(2.0 \text{ cu yd})}{\text{cycle}} \times \frac{(1 \text{ cycle})}{36 \text{ sec}} = \frac{0.056 \text{ cu yd}}{\text{sec}}$$

$$Q = \frac{(0.056 \text{ cu yd})}{\text{sec}} \times \frac{(.765 \text{ m}^3)}{\text{cu yd}}$$

$$\times \frac{1378 \text{ kg}}{\text{m}^3} = 5.9 \times 10^7 \text{ mg/sec}$$

Suspended Material (q)

$$q = 0.01 (5.9 \times 10^7 \text{ mg/sec}) = 5.9 \times 10^5 \text{ mg/sec}$$

Vertical Thickness (D)

Average Depth = 5.5 ft = 168 cm

D = 0.5 (168) = 84 cm

Diffusion Velocity (w)

Lakes and Rivers = 0.5 cm/sec

Settling Velocity (Vs)

Mean Particle Diameter = 0.082 mm

Vs = 0.3 cm/sec

TABLE 2-8 Concluded

Age of Plume (t)

$$t = \frac{84}{0.3} = 280 \text{ sec}$$

Stream Velocity (u)

Range: = 0.30 to 1.1 ft/sec

Use Average: = 21 cm/sec

CSF

$$\frac{5.9 \times 10^5}{\pi(.25)(84)(280)} = 32 \text{ mg/cc} = 3.2 \times 10^4 \text{ mg/l}$$

$$w/u = \frac{0.5}{21} = 0.02$$

$$\gamma = \frac{(0.3)(280)}{84} = 1.0$$

Centerline Concentration

At ut = 21 (280) = 5880 cm = 193 ft
C = 0.006 (32,000) = 192 mg/l

At 0.52 ut = 100 ft
C = 7 (192) = 1340 mg/l

At 0.26 ut = 50 ft
C = 20 (192) = 3840 mg/l

At 1.1 ut = 212 ft
C = 0.01 (192) = 19.2 mg/l

At 1.9 ut = 370 ft
C = 0.0001 (192) = <1 mg/l

(diameter of 0.33 mm and settling velocity of 0.06 cm/sec) would give a maximum settling distance of about 560 feet downstream, assuming a stream velocity of 33.5 cm/sec. For the major perennial crossing type, this worst case settling distance would be over 60,000 feet downstream, while for the bayou example it would be over 2500 feet downstream, assuming no intervening reservoirs and no induced settling by adsorption or aggregation with other particles.

2.E EVALUATION OF EFFECTS

Suspended Sediments

In order to assess the significance of these projected increases, available U.S. Geological Survey Water Resources Data (1970-78) for measurements of suspended sediment levels have been assembled (Table 2-9). These data indicate the maximum naturally occurring levels recorded for the streams and rivers crossed by the proposed or alternative system.

Intermittent Crossings. Suspended sediment concentrations in intermittent streams vary with the flow. Sediment concentrations typically peak prior to the peak of the hydrograph and decrease thereafter. Because construction would not take place during periods of peak flow, a direct increase in suspended sediment levels is unlikely in intermittent creeks. This would apply to the proposed action, market alternative, barge alternative, and Colorado alternative systems. The disturbed material in the bed and bank would be subject to erosion during the first flow following construction, likely resulting in an increase in sediment concentration above normal levels. These resulting in-stream concentrations would not likely be significantly greater than normal background levels.

Major and Minor Perennial Crossings. Major rivers sampled in Oklahoma, Kansas, and Nebraska have recorded levels of suspended sediments of 1000 to 3000 mg/l. Recorded maximum suspended sediment levels in the Platte River, Nebraska exceed 10,000 mg/l. Levels recorded in Arkansas approach 400 mg/l. These maximum recorded levels commonly occur during peak or flood flows.

TABLE 2-9

RANGE IN RECORDED SUSPENDED SEDIMENT CONCENTRATION
AT REPRESENTATIVE RIVERS NEAR PROPOSED
OR ALTERNATIVE CROSSINGS

Location	Period of Record	Suspended Sediment (mg/l)
White River at Newport, Arkansas (07074500)	1977 - 78	53 - 157
Verdigris River near Orola, Oklahoma (07178620)	1974 - 75	20 - 604
	1975 - 76	28 - 875
	1976 - 77	13 - 254
	1977 - 78	27 - 772
Arkansas River below Little Rock, Arkansas (07263620)	1975 - 76	13 - 87
	1976 - 77	5 - 367
	1977 - 78	20 - 64
Red River at Alexandria, Louisiana (07355500)	1972 - 73	98 - 2350
	1973 - 74	189 - 3846
	1974 - 75	111 - 4210
Platte River at Louisville, Nebraska (06805500)	1973 - 74	110 - 11,600
	1974 - 75	178 - 10,500
	1975 - 76	60 - 9,600
	1976 - 77	75 - 8,830
North Platte River at Lisco, Nebraska (06686000)	1973 - 74	219 - 593
	1974 - 75	200 - 1,920
	1975 - 76	118 - 1,570
	1976 - 77	58 - 3,840
South Fork Ninnescah River near Murdock, Kansas (07145200)	1973 - 74	1,290 - 3,280
North Fork Ninnescah River above Cheney Reservoir, Kansas (07144780)	1973 - 74	16 - 1,180
	1975 - 76	35 - 393
	1977 - 78	81 - 350

TABLE 2-9 Concluded

Location	Period of Record	Suspended Sediment (mg/l)
Arkansas River at Arkansas City, Kansas (07146500)	1973 - 74 1975 - 76	793 - 1,670 39 - 458
Arkansas River near Kinsley, Kansas (07140000)	1975 - 76 1977 - 78	8 - 377 126 - 1,360
Bayou LaFourche, Louisiana (07380400)	1959 - 76	19 - 689
Mississippi River near Arkansas City, Arkansas	1974 - 80	18 - 548
Mississippi River near Plaquemine, Louisiana (07374120)	1954 - 80	16 - 8,701
Mississippi River near Francisville, Louisiana (07373420)	1978 - 80	154 - 539

Source: U.S. Geological Survey 1973-78.

Similarly, suspended sediment levels reach a maximum in minor perennial streams during peak flows.

Because pipeline construction would not take place during periods of potential peak flow, the projected incremental increase due to construction activities would not be expected to increase levels above naturally occurring maximum levels, beyond 100 to 500 feet from most construction operations, based upon available recorded data. The majority of suspended sediments in major and minor perennial streams, generally sands or silty sands for the majority of crossings, would settle within about 50 to 200 feet of construction activities with measurable increases above background occurring from 300 to 500 feet downstream of many minor crossings. Dredging operations could generate measurable increases up to 1000 to 5000 feet downstream. Increases above naturally occurring maximum levels may take place immediately downstream (less than about 50 feet) of construction operations. These increases would be short-term in nature (limited to the period of construction) and the levels of suspended sediments would return to ambient background levels immediately after cessation of construction activity. Finer particles could travel greater distances downstream, perhaps exceeding several miles for major crossings.

Because of the settling of the majority of disturbed sediments, the high naturally occurring maximum levels of suspended sediments and the temporary nature of high increases in levels of suspended sediments immediately down stream of construction activities, water quality alterations are considered to be insignificant for major and minor perennial stream crossings for the proposed action, market, barge, and Colorado alternatives.

Bayou/Wetland Crossings. Trenching activities at bayou crossings, typically at low stream velocities, result in the potential for the generation of the suspended sediment levels as shown in Table 2-8. Levels are estimated to increase to approximately 4000 mg/l at 50 feet, dropping to less than 1 mg/l at about 400 feet downstream. Immediately adjacent to the construction activities (up to about 50 feet downstream), levels are estimated to exceed 4000 mg/l.

Few historical data on suspended solids levels are available for small bayou waterways. On the Red River, maximum levels exceeding 4000 mg/l have been recorded (Table 2-9). At these levels, the temporary increases created by construction activities would not exceed naturally occurring maximum levels at distances beyond 50 to 100 feet.

Data for the Bayou LaFourche, Louisiana, indicates maximum naturally occurring levels less than 1,000 mg/l, measured by the U.S.G.S. as the velocity-weighted concentration of suspended sediment in the sampled zone (from the water surface to a point approximately 0.3 ft above the bed) (Table 2-9). The level of suspended solids, generated by bayou/wetland construction activities would exceed this level up to distances of 100 to 200 feet downstream. Higher than naturally occurring maximum levels would be expected less than 50 feet downstream from construction activities. These increased levels immediately downstream would return to near-ambient background levels immediately after cessation of construction activities. Finer particles could travel farther downstream possibly exceeding 2500 feet before settling completely to the channel bottom.

Because of the temporary period of construction, the high levels of suspended sediments reached immediately adjacent to the construction activity would not generate a significant or irreversible alteration in water quality. Farther downstream, increases in fine particles of suspended solids could temporarily exceed naturally-occurring maximum levels. The impact could thus be significant on a short-term basis, at distances of up to perhaps 200 feet downstream. Significant long term, or irreversible, alteration in water quality would not occur. These effects would pertain to the proposed action and market alternative only. In general, the construction activity associated with crossing any perennial body of water would agitate the bed and cause a short-term increase in suspended sediments. However, the sediment would be in the water for a short period of time and affect only short reaches of stream; therefore, the total impact upon water quality would be insignificant.

Oxygen Demand and Other Parameters

Dredging or trenching activities could temporarily alter the levels of dissolved organic and inorganic constituents and exert a temporary oxygen demand in downstream receiving waters.

In an undisturbed state, streambed materials would be expected to exist in an environment characteristically low in oxidation-reduction (redox) potential and pH, which could favor the soluble ionic form of many of the trace or heavy metals of potential concern. During dredging, non-acid, oxidizing conditions would favor insoluble forms. For example, as sediments are oxidized, water-soluble or exchangable fractions of iron could precipitate as ferric hydroxide. Hydrous oxides of manganese (MnO_2) would also be expected to precipitate under oxidizing conditions. These hydrous oxides have been shown (Khalid et al. 1977 and others) to adsorb other metals; freshly formed precipitates are more effective than aged precipitates in scavenging other metals during dredging, probably due to the larger surface area and less defined crystal structure immediately following formation. In general, then, oxidizing conditions associated with dredging or trenching (e.g. resuspending reduced materials in the water column) are expected to limit the release of soluble fractions of trace metals due to precipitation of the hydrous oxide forms, as well as due to secondary co-precipitation reactions.

Processes which could counter these trends could include the release of sulfide-bound metals, via sulfate, thiosulfate or sulfur complex production, or the formation of soluble organo-metallic complexes. Recent investigations (Gambrell et al. 1977) at several dredging sites (including the Calcasieu and Mississippi rivers) indicated that most metal-sulfide complexes will remain stable during a brief exposure to an oxygenated aqueous environment, before becoming part of the reduced sediments at the disposal site. Release of sulfide-bound metals would, however, be more significant during land storage of sediments, where, over time, oxidation accompanying gradual drainage could occur. In laboratory investigations (Gambrell et al. 1977) in which pH and redox potential were varied for dredged sediment samples, no significant release of sulfide-bound metals occurred when the redox potential was raised beyond the stability boundary for sulfide, indicating that other processes, such as metal

complex formation with insoluble organics or oxides, may be the principal regulating factor.

Theis and Singer (1974) have demonstrated that complexation of ferrous iron with naturally occurring soluble organic materials may result in quantities of iron remaining in solution. Dredging investigations (Gambrell et al. 1977), indicate that complexation of ferrous iron with soluble organic material is only weakly bound, and may be released from organic chelates; because organic complexes would be present at a small proportion of total metals, the precipitation and co-precipitation reactions previously discussed would likely not be affected.

A temporary oxygen demand would be exerted during trenching or dredging activities due to chemical oxidation of inorganic constituents and biochemical oxidation of organic materials. Test boring logs indicate that streambed materials in Louisiana may be composed of up to 16 percent organic material (Table 2-6). Empirical data relating trenching or dredging operations to dissolved oxygen levels (DO) in receiving waters are generally limited. Dredged sediment released by open water dumping depressed oxygen levels by 1 to 2 mg/l during the passage of a turbid plube, over a period of 10 to 20 minutes, before DO returned to ambient (5 to 7 mg/l) levels (Blom et al. 1976). Because of the entrainment of oxygen-rich surface waters during dumping, and other hydrodynamic factors, site-specific investigations would be required in order to predict the exact magnitude and duration of oxygen depletion.

The greatest amount of oxygen-demanding organic materials would be encountered in the bayou/wetland areas of Louisiana. Available surface water records (U.S. EPA STORET 1970-78) for the Atchafalaya Basin, Louisiana, show that mean DO levels may range from 3 to 6 mg/l, with levels as low as 0.2 mg/l reached. Unless trenching took place during stagnant, extreme low DO periods, the incremental decrease in DO levels caused during construction would not be expected to depress DO levels below naturally occurring minimum levels, nor to irreversibly alter receiving water quality; e.g., induced re-aeration would be expected to return DO levels to background levels shortly (within one day) after cessation of trenching activities.

In summary, oxidizing conditions during trenching would be expected to precipitate or co-precipitate soluble trace metals present in streambed materials. Dredged sediments would exert a temporary oxygen demand especially along the Louisiana portion of the route, but DO levels are not expected to be reduced below naturally occurring levels, or be irreversibly altered.

Chapter 3
HYDROSTATIC TEST WATER DISCHARGE

3.A HYDROSTATIC TEST WATER REGULATIONS

The proposed and alternative pipeline systems are within three designated regions of the U.S. Environmental Protection Agency. These are: Region 8 (Wyoming and Colorado); Region 7 (Kansas and Nebraska); and Region 6 (Arkansas, Louisiana, and Oklahoma). The discharge of pollutants from point sources, including hydrostatic test water into waters of the United States, would be unlawful without a permit issued under the National Pollutant Discharge Elimination System (NPDES). Administration of NPDES permits may be transferred to individual states, if authorized by the Administrator of the U.S. EPA. To date, Wyoming, Colorado, Kansas, and Nebraska have been authorized to issue NPDES permits (Shanklin 1980; Reed 1980; and Preston 1980). Oklahoma, Arkansas, and Louisiana have not assumed such authority (Dean 1980).

At this time uniform federal standards of performance for the discharge of hydrostatic test water have not been promulgated (Shanklin 1980). Authorization for the discharge of test water would be required from either the U.S. EPA (with concurrence of the state) or the individual authorized states. In Oklahoma, Arkansas, and Louisiana (Region 6) an NPDES permit would be required from the U.S. EPA, Region 6 (Dean 1980) in addition to state discharge permits. At least 180 days prior notice would be required. Short Form C, with supplementary information as necessary, could be used for permit application (Dean 1980).

In Wyoming, authorization for discharge would be required from the Wyoming Department of Environmental Quality; chemical analyses of test water to be used and locations and amounts of discharge would be required; detention ponds to reduce suspended solids levels to approximately 30 mg/l would also be required (Stroman 1980). In Colorado, authorization from the Colorado Department of Health would be required; no standard guidelines exist, but Colorado Basic Effluent Discharge Standards for total suspended solids (45 mg/l) and grease (no visible sheen) and erosion control may be required (Snyder 1980). In Nebraska, authorization from the Department of Environmental Control would

be required (Preston 1980). In Kansas, authorization would be required from the Department of Health and Environment (Jensen 1980).

3.B HYDROSTATIC TEST WATER DISCHARGE

During the construction operation, the pipeline would be hydrostatically tested to 125 percent of maximum operating pressure. Water would be obtained from local ground or surface water supplies, with up to a maximum of 28 acre feet (9.2 million gallons) of water required for the largest single discharge for the proposed action, market, and barge alternatives, and 49 acre feet (16 million gallons) for the Colorado alternative.

As a result of hydrostatic testing, the levels of suspended solids, iron, grease and oil could potentially increase in the test water. Table 3-1 presents a summary of water quality monitoring data collected before and after hydrostatic tests, using ground, surface, and municipal waters. As expected, the constituent showing the greatest increase is iron.

Without adequate treatment, the discharge of hydrostatic test water could increase the levels of turbidity, iron, oil and grease, and decrease the levels of dissolved oxygen in receiving waters. This would be especially significant in low flowing surface waters. This would be especially significant in low flowing surface waters, which would have low assimilative capacities. Without adequate flow control, erosion could also occur at local discharge sites. For the highest volume of test water required (16 million gallons), uncontrolled (instantaneous) discharge over a short period could significantly increase local surface waters. For example, discharge of this volume over 24 hours would represent a continuous discharge exceeding 25 cubic feet per second. This level would exceed the annual average flow level of most rivers crossed except for the major perennial rivers.

3.C SUMMARY OF EFFECTS

The uncontrolled discharge of hydrostatic test water could significantly increase surface water flows, potentially resulting in localized erosion. Levels

TABLE 3-1

HYDROSTATIC TEST WATER ANALYSES

Parameter	Water Source									
	Pond		Well		Creek		River		Municipal	
	Fill	Dewater	Fill	Dewater	Fill	Dewater	Fill	Dewater	Fill	Dewater
Fe (mg/l)	0.56	13.2	0.2	14.0	1.3	1.3	0.2	2.6	2.7	0.4
TSS (mg/l)	69	61	8	120	-	-	-	-	-	-
SO_4 (mg/l)	17	142	-	-	-	-	26.8	30.3	8.0	7.2
Cl (mg/l)	0.8	0.7	-	-	-	-	52.5	36.0	4.0	3.0
F (mg/l)	0.4	0.4	-	-	-	-	0.4	0.4	1.1	1.1
COD (mg/l)	68.0	34.0	1.0	1.0	38.0	10.0	-	-	-	-
Hardness (mg/l)	64.0	60.0	-	-	-	-	48.0	40.0	26.0	26.0
Alkalinity (mg/l)	78.0	58.0	-	-	-	-	26.0	20.0	18.0	18.0
pH	7.3	7.3	7.7	7.9	5.8	6.3	6.9	6.6	7.6	7.5

Source: Young 1980.

of suspended solids, grease, oil, and iron could temporarily increase downstream of discharge sites. Depending upon the specific discharge location, downstream uses, including recreation, aquatic habitat, or municipal water supply could be temporarily impaired.

Chapter 4
STREAM FLOW REDUCTIONS

4.A SUMMARY OF EFFECTS

As a result of groundwater withdrawals from the Madison formation, worst-case flow reductions have been estimated for several South Dakota and Wyoming streams and rivers (see Hydrology Technical Report, WCC 1981).

Reduced streamflows could result in slightly higher ambient temperatures and correspondingly lower levels of dissolved oxygen, and possibly higher concentrations of dissolved constituents due to increased evaporation. These effects cannot be accurately quantified or predicted due to insufficient streamflow gaging records and a variety of other intervening factors, e.g., irrigation withdrawals and returns, seasonal and climatic variables, etc.

Another effect, which can be quantified, is the reduction in wastewater assimilative capacity in affected streams. This effect refers to the lower amount of dilution which would be available to wastewater dischargers in reaches of streams or rivers which were reduced in flow. This chapter will evaluate this potential reduction in wastewater assimilative capacity in all potentially affected streams and rivers.

4.B CITY OF HOT SPRINGS

As a response to the DEIS (Comment #138), the South Dakota Department of Water and Natural Resources (DWNR) has evaluated the effect of the estimated flow reduction in the Fall River as it would affect the waste assimilative capacity available to the city of Hot Springs. Relevant portions of this comment appear as follows (South Dakota Department of Water and Natural Resources 1981).

Most of the streams in the Black Hills are classified as water quality limited segments under the U.S. Environmental Protection Agency's Continuing Planning Process established pursuant to Section 303(e) of the Federal Clean Water Act. This means that wastewater dischargers to these streams must meet more stringent effluent limitations than those required for secondary treatment in the case of municipal dischargers. Therefore, the effluent limitations for most dischargers in the Black Hills area are based on requirements for meeting State in-stream standards and are determined by the development of a wasteload allocation (WLA). In the WLA process the amount of flow available for dilution and assimilation of wastes in the receiving stream under low flow conditions is an extremely important variable. The more flow available the less restrictive are the treatment requirements, and conversely the less flow available the more restrictive are the treatment requirements. By regulation, the design low flow conditions for use in the WLA process are the 7 consecutive day-25 year low flow for cold water fishery waters and warm water permanent fisheries while the 7 consecutive day-5 year low flow is used for warm water semi-permanent and marginal fisheries. In either case, these statistical low flow conditions represent base flows, and any reduction in base flows of wastewater effluent receiving streams will require that more stringent and costly treatment be provided by the discharger.

DWNR has analyzed the impacts on treatment requirements and costs for the City of Hot Springs which would result from reduced base flows in the Fall River as projected by the draft EIS. The analysis which is included as Attachment 4 shows that effluent ammonia limitations would be reduced from 7.7 mg/l at present to 5.3 mg/l during the winter season and from 6.8 mg/l at present to 3.9 mg/l during the summer season with a decrease in base flow of 2 cfs as projected in the draft EIS. If the reduction in base flow should be 4 cfs, the ammonia limitations would be further reduced to 4.7 mg/l and 3.4 mg/l respectively for the winter and summer seasons. It is estimated that the increased treatment requirements for ammonia removal would substantially increase the City of Hot Springs' annual costs for operation and maintenance and construction debt retirement for upgrading its wastewater treatment system to meet these more stringent limits.

The 201 Facility Plan prepared by the City of Hot Springs in 1975 showed that a highly technological mechanical wastewater treatment plant would increase the annual equivalent cost $218,000 above the costs required for a less sophisticated mechanical plant. The reduction in base flow and the subsequent lowering of allowable ammonia limitations will require that the City either construct additional mechanical treatment capabilities beyond that now planned or go to an alternate treatment method, such as land application. It has been estimated that land application would increase the capital costs for upgrading the City's plant by $2.2 million dollars, which equates to an annual increase in cost of $210,000. Therefore, depending on the degree of flow reduction in the Fall River, it is

estimated that cost increases to upgrade the City's wastewater treatment facility could easily range up to an additional $100,000-$200,000 per year.

CALCULATIONS

Ammonia Limitations for a Seasonal Beneficial Use Classification For Fall River

From the EIS, it is stated that a decrease of 2 cfs will be caused by the pumping from the Madison aquifer.

	SEASON	
	Winter	Summer
7 Day - 25 Year Low Flow	16.0	15.1
7 Day - 25 Year Low Flow less 2 cfs reduction	14.0 cfs	13.1 cfs
Background instream (NH_3-N) mg/l	.02	.02
Average Temp. in degrees Celsius	13.7	23.8
Average pH, standard units	8.2	8.3
Allowable instream NH_3-N (mg/l)	.55	.43
Proposed design effluent flow in cfs	1.55	1.55
Downstream low flow of Fall River in cfs	17.55	16.65
Downstream low flow of Fall River less 2 cfs reduction	15.55 cfs	14.65 cfs

Calculations of Ammonia Limitations for Winter - 2 cfs Depletion

Flow (Down) Stream	Allowable Total (Ammonia) Conc.	Plant (Design) Flow	Effluent (Ammonia) Limitations	Flow (up) Stream	Ambient (Ammonia) Conc.

(15.55)(0.55) = (1.55)(TN) + (14.0)(0.02) where TN = Allowable effluent ammonia concentration

.: Winter Season Effluent Ammonia Limitation = TN = 5.3 mg/l
Present Effluent Ammonia Limitation = 7.7 mg/l

Calculation of Ammonia Limitations for Summer

(14.65)(0.43) = (1.55)(TN) + (13.1)(0.02) where TN - Allowable effluent ammonia concentration

.: Summer Season Effluent Ammonia Limitation = TN = 3.9 mg/l
Present Eff. Ammonia Limitation = 6.8 mg/l

Calculations of Ammonia Limitation for Winter - 4 cfs Depletion

Flow (Down) Stream	Allowable Total (Ammonia) Conc.	Plant (Design) Flow	Effluent (Ammonia) Limitations	Flow (up) Stream	Ambient (Ammonia) Conc.

$(13.55)(0.55) = (1.55)(TN) + (12.0)(0.02)$ where TN = Allowable effluent ammonia concentration

.: Max. Effluent Ammonia Limitation for the Winter Season = TN = 4.7 mg/l

Calculation of Ammonia Limitation for Summer - 4 cfs Depletion

$(12.65)(0.43) = (1.55)(TN) + (11.1)(0.02)$

.: Max. Effluent Ammonia Limitations for the Summer Season = TN = 3.4 mg/l

The city of Hot Springs is presently in the process of upgrading its sewage treatment works. The existing NPDES Permit (Number SD-0022918) specifies that the City shall complete its Facility Plan construction and achieve compliance with effluent limitations by July 1, 1983. NPDES permits are issued by the U.S. EPA for five year periods. The Facility Plans for treatment plan replacement or upgrading are generally designed for 20 year periods, e.g., based upon 20-year population projections. The estimated maximum streamflow reduction of 2 cfs is considered to be a highly conservative, worst case estimate for flow reduction. Additional modeling outputs have projected the reduction for 5, 10, 25, and 50 years (Table 4 - FEIS).

Based upon these projections, the estimated ammonia effluent limitations would change as shown in Table 4-1, based on the same methodology as used by the South Dakota DWNR.

As shown in Table 4-1, a change in effluent limitation would occur for Plans 1, 2, 5, and 6, with no change for Plans 3 and 4. The reduction in effluent limits estimated for 25 years (Plans 1, 2, and 6, could directly affect the operation of the facilities now being designed (20 year design). The effects estimated for 50 years, could affect future facility operation, depending upon future effluent limits and future facility expansion.

TABLE 4-1

EFFECT OF ESTIMATED STREAMFLOW REDUCTIONS ON
WASTE ASSIMILATIVE CAPACITY OF FALL RIVER
(City of Hot Springs)

Existing Effluent Limitation for Ammonia (NH_3-N)	Effluent Limitation for Ammonia (NH_3-N) after ETSI Begins Pumping (mg/l)			
	5 Years (1990)	10 Years (1995)	25 Years (2010)	50 Years (2035)
Summer Season: 6.8 mg/l				
Plan 1	NC*	NC	4.2	3.9
Plan 2	NC	NC	4.2	4.2
Plan 3	NC	NC	NC	NC
Plan 4	NC	NC	NC	NC
Plan 5	NC	NC	NC	4.2
Plan 6	4.2	4.2	3.9	3.9
Winter Season: 7.7 mg/l				
Plan 1	NC	NC	5.7	5.3
Plan 2	NC	NC	5.7	5.7
Plan 3	NC	NC	NC	NC
Plan 4	NC	NC	NC	NC
Plan 5	NC	NC	NC	5.7
Plan 6	5.7	5.7	5.3	5.3

*NC = No change.

4.C OTHER SOUTH DAKOTA AND WYOMING DISCHARGERS

The information developed by the South Dakota DWNR and updated with modeling outputs is sufficient to evaluate the potential impacts upon waste assimilative capacity as a result of projected flow reductions to Hot Springs. The effect upon waste assimilative capacities for all other spring and streamflow reductions has also been evaluated. The following methodology has been used to complete this evaluation.

1) Affected reaches of receiving streams were identified, from the location of projected flow reductions, downstream to the first reservoir.

2) Municipal or industrial waste water sources, with permits to discharge into the affected stream reaches, were identified.

3) Discharge permits (NPDES) were inventoried and reviewed, and specific numerical effluent limitation (if any) based on background flow were identified.

4) If applicable, the change in any numerical effluent limitations that are based on background flow were calculated, using the projected instream flow reductions that could occur as a result of ETSI.

The results of this investigation are as follows.

Wyoming

In Wyoming, projected flow reductions could affect reaches of five streams or rivers: Sand Creek, Belle Fourche River, Little Missouri River, Cheyenne River, and Stockade-Beaver Creek. Of these, the only known discharger is into the Belle Fourche River at Hulett (Wagner 1981). One NPDES permit limitation would be affected, the effluent limitation for residual chlorine. It would be reduced (e.g., the limit would be made more stringent) as shown in Table 4-2.

TABLE 4-2

EFFECT OF ESTIMATED STREAMFLOW REDUCTIONS ON
WASTE ASSIMILATIVE CAPACITY OF BELLE FOURCHE RIVER
(Town of Hulett)

	Effluent Limitation for Residual Chlorine after ETSI Begins Pumping (mg/l)			
	5 Years (1990)	10 Years (1995)	25 Years (2010)	50 Years (2035)
Plan 1	0.22	0.22	0.19	0.19
Plan 2	0.19	0.19	0.19	0.15
Plan 3	0.19	0.15	0.12	0.12
Plan 4	0.19	0.15	0.12	0.12
Plan 5	0.19	0.19	0.15	0.12
Plan 6	0.19	0.19	0.15	0.12

Existing effluent limitation for residual chlorine: 0.25 mg/l.

These reductions are the worst case estimations and assume the entire streamflow reduction of the Belle Fourche River occurs upstream of Hulett (actual estimations are for the reach of the Belle Fourche River all the way to the state border).

At the present time, the town of Hulett is in the planning process for design of upgraded wastewater treatment facilities, with completion of construction scheduled for November 1, 1981. In order to meet the reduced effluent limitations, especially under Plans 3 and 4 modifications to the treatment facilities would be required, such as increased chlorine contact chamber size or dechlorination facilities. The incremental costs for these types of modifications are unknown at this time.

South Dakota

Two dischargers have been identified downstream of potential flow reductions: the city of Hot Springs (Fall River) and the city of Spearfish (Redwater River). The impacts to the city of Hot Springs have already been discussed. The city of Spearfish is presently in the planning process for design of wastewater treatment facilities that would discharge into the Redwater River.

The permit requirements for this facility do not include effluent limitations (such as ammonia) which are based on background flow conditions, since the 25 year 7 day design low flow for the Redwater River may reach 0, e.g., estimated to be 0 to 10 cfs (Pirner 1981). Since the treatment facility may discharge at 0 background flow, without ETSI, no direct affect upon facility design, related to effluent limitation are anticipated.

Several other industrial dischargers were identified (e.g., feedlots) downstream of flow reductions. However, since NPDES permits will require Best Available Technology and zero discharge by 1984, no effluent limitation affects are anticipated at these locations.

North Dakota

Two permitted dischargers to the Little Missouri River were identified: the cities of Marmarth and Medora (Kuhn 1981). Based upon existing NPDES

permits for treatment facilities for these cities (ND-0020184 and ND-0022799) no effluent limitations that are based on background flow conditions would be affected.

Montana

No dischargers on the Little Missouri River were identified (Schuman 1981).

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APPENDIX
STREAM CROSSINGS

Table A-1 LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS THAT WOULD BE CROSSED BY THE PROPOSED NIOBRARA WELL FIELD WATER SUPPLY LINE THROUGH WYOMING
I = Intermittent; P (Major) = Major Perennial; P (Minor) = Minor Perennial; UT = Unnamed Tributary

Stream	Flow	County
UT Little Thunder Creek	I	Campbell
UT Little Thunder Creek	I	Campbell
Little Thunder Creek	I	Campbell
UT Little Thunder Creek	I	Campbell
UT Little Thunder Creek	I	Campbell
UT Piney Creek	I	Weston
UT Piney Creek	I	Weston
UT Piney Creek	I	Weston
Frog Creek	I	Weston
UT Frog Creek	I	Weston
UT Frog Creek	I	Weston
Keyton Creek	I	Converse
Cheyenne River	I	Converse
Wagon Hound Creek	I	Niobrara
UT Wagon Hound Creek	I	Niobrara
UT Wagon Hound Creek	I	Niobrara
Snyder Creek	I	Niobrara
Dogie Creek	I	Niobrara
UT Dogie Creek	I	Niobrara
UT Dogie Creek	I	Niobrara
UT Dogie Creek	I	Niobrara
UT Dogie Creek	I	Niobrara
UT Dogie Creek	I	Niobrara
Lance Creek	I	Niobrara
UT Lance Creek	I	Niobrara
Crazy Woman Creek	I	Niobrara
UT Crazy Woman Creek	I	Niobrara
Unnamed stream	I	Niobrara
UT Lance Creek	I	Niobrara
UT Lance Creek	I	Niobraa
Old Woman Creek	I	Niobrara
UT Old Woman Creek	I	Niobrara

Total Crossings

Intermittent: 32

Table A-2 LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS THAT WOULD BE CROSSED BY THE CROOK COUNTY WELL FIELD WATER SUPPLY LINE ALTERNATIVE THROUGH WYOMING
I = Intermittent; P (Minor) = Minor Perennial; UT = Unnamed Tributary

Stream	Flow	County
UT Little Missouri River	I	Crook
UT Mud Creek	I	Crook
Mud Creek	I	Crook
UT Little Missouri River	I	Crook
UT Little Missouri River	I	Crook
UT Prarie Creek	I	Crook
Prairie Creek	I	Crook
UT Prarie Creek	I	Crook
Prairie Creek	I	Campbell
Spring Creek	I	Campbell
UT Spring Creek	I	Campbell
UT Spring Creek	I	Campbell
Cottonwood Creek	P (Minor)	Campbell
UT Cottonwood Creek	I	Campbell
UT Cottonwood Creek	I	Campbell
UT Cow Creek	I	Campbell
UT Cow Creek	I	Campbell
Corral Creek	I	Campbell
Little Powder River	I	Campbell
Dry Fork Little Powder River	I	Campbell

Total Crossings

Intermittent: 19
Perennial (Minor): 1

Table A-3 LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS THAT WOULD BE CROSSED BY THE OAHE ALTERNATIVE WATER SUPPLY LINE THROUGH SOUTH DAKOTA
I = Intermittent; UT = Unnamed Tributary

Stream	Flow	County
*		
Willow Creek	I	Stanley
UT Willow Creek	I	Stanley
UT Willow Creek	I	Stanley
UT Willow Creek	I	Stanley
UT Lance Creek	I	Stanley
UT Lance Creek	I	Stanley
UT Lance Creek	I	Stanley
UT Lance Creek	I	Stanley
UT Lance Creek	I	Stanley
UT Plum Creek	I	Stanley
UT Plum Creek	I	Stanley
UT Plum Creek	I	Stanley
UT Plum Creek	I	Stanley
UT Plum Creek	I	Stanley
UT Plum Creek	I	Stanley
UT Plum Creek	I	Stanley
UT Plum Creek	I	Stanley
UT Plum Creek	I	Stanley
UT Plum Creek	I	Stanley
Cottonwood Creek	I	Haakon
UT Plum Creek	I	Haakon
UT Plum Creek	I	Haakon
UT Plum Creek	I	Haakon
UT Mule Creek	I	Haakon
UT Mule Creek	I	Haakon
UT West Plum Creek	I	Haakon
UT West Plum Creek	I	Haakon
UT West Plum Creek	I	Haakon
UT West Plum Creek	I	Haakon
UT West Plum Creek	I	Haakon
UT West Plum Creek	I	Haakon
UT Snake Creek	I	Haakon
UT Snake Creek	I	Haakon
UT Snake Creek	I	Haakon
UT Snake Creek	I	Haakon
UT Snake Creek	I	Haakon
UT Snake Creek	I	Haakon
UT Bridger Creek	I	Haakon
UT Bridger Creek	I	Haakon
UT Ash Creek	I	Haakon
UT Ash Creek	I	Haakon

* A section 10 permit would be required for the Oahe Reservoir.

Total Crossings

Intermittent: 41

Table A-3 (continued)
I = Intermittent; P (Major) = Major Perennial; UT = Unnamed Tributary

Stream	Flow	County
UT Ash Creek	I	Haakon
UT Deep Creek	I	Pennington
UT Deep Creek	I	Pennington
UT Deep Creek	I	Pennington
UT Deep Creek	I	Pennington
UT Deep Creek	I	Pennington
UT Deep Creek	I	Pennington
UT Cheyenne River	I	Pennington
UT Cheyenne River	I	Pennington
UT Cheyenne River	I	Pennington
UT Cheyenne River	I	Pennington
UT Cheyenne River	I	Pennington
UT Cheyenne River	I	Pennington
Cheyenne River	P (Major)	Pennington
UT Elk Creek	I	Pennington
UT Elk Creek	I	Pennington
UT Elk Creek	I	Pennington
UT Elk Creek	I	Pennington
UT Elk Creek	I	Pennington
Elk Creek	I	Meade
UT Elk Creek	I	Meade
UT Elk Creek	I	Meade
UT Elk Creek	I	Meade
UT Elk Creek	I	Meade
UT Elk Creek	I	Meade
UT Elk Creek	I	Meade
UT Elk Creek	I	Meade
UT Elk Creek	I	Meade
UT Elk Creek	I	Meade
UT Elk Creek	I	Meade
UT Elk Creek	I	Meade
UT Elk Creek	I	Meade
UT Elk Creek	I	Meade
UT Elk Creek	I	Meade
UT Elk Creek	I	Meade
UT Elk Creek	I	Meade
UT Elk Creek	I	Meade
UT Antelope Creek	I	Meade
UT Antelope Creek	I	Meade
Antelope Creek	I	Meade
UT Antelope Creek	I	Meade

Total Crossings

Intermittent: 40
Perennial (Major): 1

Table A-3 (concluded)
I = Intermittent; P (Minor) = Minor Perennial; UT = Unnamed Tributary

Stream	Flow	County
UT Antelope Creek	I	Meade
UT Antelope Creek	I	Meade
UT Alkali Creek	I	Meade
UT Alkali Creek	I	Meade
UT Alkali Creek	I	Meade
UT Alkali Creek	I	Meade
UT Alkali Creek	I	Meade
UT Alkali Creek	I	Meade
UT Alkali Creek	I	Meade
UT Bear Butte Creek	I	Meade
Bear Butte Creek	P (Minor)	Meade
UT Bear Butte Creek	I	Meade
UT Bear Butte Creek	I	Meade
UT Spring Creek	I	Meade
Spring Creek	I	Meade
UT Spring Creek	I	Lawrence
Whitewood Creek	P (Minor)	Lawrence
UT Whitewood Creek	I	Lawrence
UT Redwater River	I	Lawrence
UT Redwater River	I	Lawrence
UT Redwater River	I	Lawrence
UT Redwater River	I	Lawrence
UT Redwater River	I	Lawrence
UT Redwater River	I	Lawrence
UT Redwater River	I	Lawrence
Spearfish Creek	P (Minor)	Lawrence
Crow Creek	I	Lawrence
UT Chicken Creek	I	Lawrence
UT Chicken Creek	I	Lawrence
Chicken Creek	I	Lawrence
UT Redwater Creek	I	Lawrence

Total Crossings

Intermittent: 28
Perennial (Minor): 3

Table A-3a LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS THAT WOULD BE CROSSED BY THE OAHE ALTERNATIVE THROUGH WYOMING
I = Intermittent; P (Major) = Major Perennial; P (Minor) = Minor Perennial; UT = Unnamed Tributary

Stream	Flow	County
Sand Creek	P (Minor)	Crook
South Redwater Creek	P (Minor)	Crook
UT South Redwater Creek	I	Crook
Alkali Creek	I	Crook
South Redwater Creek	P (Minor)	Crook
Sundance Creek	P (Minor)	Crook
UT Sundance Creek	I	Crook
UT Beaver Creek	I	Crook
UT Beaver Creek	I	Crook
UT Beaver Creek	I	Crook
UT Beaver Creek	I	Crook
UT Beaver Creek	I	Crook
Beaver Creek	I	Crook
UT Inyan Kara Creek	I	Crook
UT Inyan Kara Creek	I	Crook
Inyan Kara Creek	P (Minor)	Crook
Arch Creek	I	Crook
Willow Creek	I	Crook
Tom Cat Creek	I	Crook
Mule Creek	P (Minor)	Crook
Wind Creek	I	Crook
UT Wind Creek	I	Crook
UT Wind Creek	I	Crook
Unnamed Stream	I	Crook
UT Belle Fourche River	I	Crook
Belle Fourche River	P (Major)	Crook
Donkey Creek	P (Minor)	Crook
UT Donkey Creek	I	Crook
UT Donkey Creek	I	Crook
UT Donkey Creek	I	Campbell
UT Donkey Creek	I	Campbell
UT Donkey Creek	I	Campbell
UT Donkey Creek	I	Campbell
UT Donkey Creek	I	Campbell
UT Donkey Creek	I	Campbell
UT Donkey Creek	I	Campbell
UT Donkey Creek	I	Campbell

Total Crossings

Intermittent: 29
Perennial (Minor): 7
Perennial (Major): 1

Table A-4 LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS WHICH WOULD BE CROSSED BY THE NORTH ANTELOPE SLURRY GATHERING LINE THROUGH WYOMING
I = Intermittent; UT = Unnamed Tributary

Stream	Flow	County
UT Porcupine Creek	I	Campbell
UT Beckwith Creek	I	Campbell
UT Beckwith Creek	I	Campbell
UT School Creek	I	Campbell
UT School Creek	I	Campbell
UT School Creek	I	Campbell
UT School Creek	I	Campbell
School Creek	I	Campbell
UT Little Thunder Creek	I	Campbell
Little Thunder Creek	I	Campbell

Total Crossings

Intermittent: 10

Table A-5 LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS THAT WOULD BE CROSSED BY THE NORTH RAWHIDE SLURRY GATHERING LINE THROUGH WYOMING
I = Intermittent; P (Major) = Major Perennial; P (Minor) = Minor Perennial; UT = Unnamed Tributary

Stream	Flow	County
UT Dry Fork Little Powder River	I	Campbell
UT Dry Fork Little Powder River	I	Campbell
UT Dry Fork Little Powder River	I	Campbell
Donkey Creek	P (Minor)	Campbell
UT Donkey Creek	I	Campbell
UT Donkey Creek	I	Campbell
UT Donkey Creek	I	Campbell
UT Donkey Creek	I	Campbell
UT Tisdale Creek	I	Campbell
Tisdale Creek	I	Campbell
Caballo Creek	I	Campbell
UT Caballo Creek	I	Campbell
UT Belle Fourche River	I	Campbell
Belle Fourche River	P (Minor)	Campbell
UT Coal Creek	I	Campbell
E. Fork Coal Creek	I	Campbell
UT Middle Fork Coal Creek	I	Campbell
UT Middle Fork Coal Creek	I	Campbell
Black Thunder Creek	I	Campbell
UT Black Thunder Creek	I	Campbell
UT Little Thunder Creek	I	Campbell

Total Crossings

Intermittent: 19
Perennial (Minor): 2

Table A-6 LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS THAT WOULD BE CROSSED BY THE PROPOSED ACTION AND MARKET ALTERNATIVE THROUGH WYOMING
I = Intermittent; UT = Unnamed Tributary

Stream	Flow	County
UT Little Thunder Creek	I	Campbell
UT Little Thunder Creek	I	Campbell
Little Thunder Creek	I	Campbell
UT Little Thunder Creek	I	Campbell
UT Little Thunder Creek	I	Campbell
UT Piney Creek	I	Weston
Piney Creek	I	Weston
Piney Creek	I	Weston
Frog Creek	I	Weston
UT Frog Creek	I	Weston
UT Frog Creek	I	Weston
Keyton Creek	I	Converse
Cheyenne River	I	Converse
Wagon Hound Creek	I	Niobrara
UT Wagon Hound Creek	I	Niobrara
UT Wagon Hound Creek	I	Niobrara
Snyder Creek	I	Niobrara
Dogie Creek	I	Niobrara
UT Dogie Creek	I	Niobrara
UT Cow Creek	I	Niobrara
UT Cow Creek	I	Niobrara
Cow Creek	I	Niobrara
UT Cow Creek	I	Niobrara
UT Cow Creek	I	Niobrara
Lightning Creek	I	Niobrara
Lightning Creek	I	Niobrara
UT Lance Creek	I	Niobrara
Lance Creek	I	Niobrara
UT Lance Creek	I	Niobrara
UT Crazy Woman Creek	I	Niobrara
UT Crazy Woman Creek	I	Niobrara
Crazy Woman Creek	I	Niobrara
UT Crazy Woman Creek	I	Niobrara
UT Crazy Woman Creek	I	Niobrara
UT Young Woman Creek	I	Niobrara
Young Woman Creek	I	Niobrara
Young Woman Creek	I	Niobrara
UT Old Woman Creek	I	Niobrara
UT Old Woman Creek	I	Niobrara
UT Old Woman Creek	I	Niobrara
Old Woman Creek	I	Niobrara

Total Crossings

Intermittent: 41

Table A-6 (Concluded)
I = Intermittent; UT = Unnamed Tributary

Stream	Flow	County
UT Old Woman Creek	I	Niobrara
Cottonwood Creek	I	Niobrara
Bergreen Creek	I	Niobrara
Niobrara River	I	Niobrara
UT Niobrara River	I	Goshen

Total Crossings

Intermittent: 5

Table A-7 LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS THAT WOULD BE CROSSED BY THE PROPOSED ACTION AND MARKET ALTERNATIVE THROUGH NEBRASKA
I = Intermittent; P (Major) = Major Perennial; P (Minor) = Minor Perennial; UT = Unnamed Tributary; 2 = 404 permit required

Stream	Flow	County
UT Niobrara River	I	Sioux
UT Niobrara River	I	Sioux
UT Niobrara River	I	Sioux
UT Whistle Creek	I	Sioux
UT Snake Creek	I	Sioux
Snake Creek	I	Sioux
Mud Springs Creek	I	Box Butte
UT Mud Springs Creek	I	Box Butte
S. Branch Snake Creek	I	Box Butte
Unnamed stream	I	Box Butte
UT Lower Dugout Creek	I	Morrill
Lower Dugout Creek	I	Morrill
UT North Platte River	I	Morrill
UT North Platte River	I	Morrill
UT North Platte River	I	Morrill
North Platte River[2]	P (Major)	Morrill
UT North Platte River	I	Morrill
Unnamed stream	I	Morrill
UT North Platte River	I	Morrill
UT North Platte River	I	Morrill
UT North Platte River	I	Garden
Rush Creek	I	Garden
UT Rush Creek	I	Garden
UT Rush Creek	I	Garden
UT Rush Creek	I	Garden
Unnamed stream	I	Garden
Unnamed stream	I	Garden
UT North Platte River	I	Garden
UT North Platte River	I	Garden
UT North Platte River	I	Garden
UT South Platte River	I	Keith
UT South Platte River	I	Keith
South Platte River[2]	P (Major)	Keith
Western Canal	P (Minor)	Keith
Unnamed stream	I	Perkins
Stinking Water Creek	P (Minor)	Chase
UT Stinking Water Creek	I	Hays
Fish Canyon Creek	I	Hays

Total Crossings

Intermittent: 34
Perennial (Minor): 2
Perennial (Major): 2

Table A-7 (concluded)
I = Intermittent; P (Major) = Major Perennial; P (Minor) = Minor Perennial; UT = Unnamed Tributary; 2 = 404 permit required

Stream	Flow	County
UT Blackwood Creek	I	Hitchcock
UT Blackwood Creek	I	Hitchcock
UT Blackwood Creek	I	Hitchcock
UT Blackwood Creek	I	Hitchcock
Blackwood Creek	P (Minor)	Hitchcock
UT Republican River	I	Red Willow
Republican River[2]	P (Major)	Red Willow
West Canal	P (Minor)	Red Willow
West Canal	P (Minor)	Red Willow
Driftwood Creek	P (Minor)	Red Willow
UT Driftwood Creek	P (Minor)	Red Willow
UT Driftwood Creek	I	Red Willow
UT Beaver Creek	I	Red Willow
Beaver Creek	P (Minor)	Red Willow

Total Crossings

Intermittent: 7
Perennial (Minor): 6
Perennial (Major): 1

Table A-8 LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS THAT WOULD BE CROSSED BY THE PROPOSED ACTION THROUGH KANSAS
I = Intermittent; P (Minor) = Minor Perennial; UT = Unnamed Tributary

Stream	Flow	County
UT Beaver Creek	I	Decatur
UT Sappa Creek	I	Decatur
UT Sappa Creek	I	Decatur
Sappa Creek	P (Minor)	Decatur
UT Sappa Creek	I	Decatur
UT Sappa Creek	I	Decatur
UT Sappa Creek	I	Decatur
UT Big Timber Creek	I	Decatur
UT Big Timber Creek	I	Decatur
UT Big Timber Creek	I	Decatur
Big Timber Creek	I	Decatur
Big Timber Creek	I	Decatur
Big Timber Creek	I	Decatur
Big Timber Creek	I	Decatur
Prairie Dog Creek	I	Decatur
UT Elk Creek	I	Decatur
UT N. Fork Solomon River	I	Norton
UT N. Fork Solomon River	I	Norton
N. Fork Solomon River	P (Minor)	Norton
UT N. Fork Solomon River	I	Norton
UT N. Fork Solomon River	I	Norton
UT N. Fork Solomon River	I	Norton
UT Bow Creek	I	Graham
UT Bow Creek	I	Graham
Bow Creek	I	Graham
UT Rock Creek	I	Graham
UT S. Fork Solomon River	I	Graham
S. Fork Solomon River	P (Minor)	Graham
Jackson Branch	I	Graham
UT Jackson Branch	I	Graham
UT Jackson Branch	I	Graham
UT Saline River	I	Graham
UT Saline River	I	Graham
UT Saline River	I	Graham
UT Saline River	I	Graham
Saline River	P (Minor)	Trego
Shaw Creek	I	Trego
UT Shaw Creek	I	Trego
UT Saline River	I	Trego
UT Spring Creek	I	Trego

Total Crossings

Intermittent: 36
Perennial (Minor): 4

Table A-8 (continued)
I = Intermittent; P (Major) = Major Perennial; P (Minor) = Minor Perennial; UT = Unnamed Tributary; 2 = 404 permit required

Stream	Flow	County
UT Big Creek	I	Trego
UT Big Creek	I	Trego
UT Big Creek	I	Trego
UT Big Creek	I	Trego
UT Big Creek	I	Trego
UT Big Creek	I	Trego
Big Creek	P (Minor)	Trego
UT Big Creek	I	Trego
UT Smoky Hill River	I	Ellis
UT Big Creek	I	Ellis
UT Smoky Hill River	I	Ellis
UT Smoky Hill River	I	Ellis
UT Smoky Hill River	I	Ellis
UT Smoky Hill River	I	Ellis
UT Smoky Hill River	I	Ellis
UT Smoky Hill River	I	Ellis
UT Smoky Hill River	I	Ellis
UT Smoky Hill River	I	Ellis
UT Smoky Hill River	I	Ellis
Smoky Hill River	P (Minor)	Ellis
UT Smoky Hill River	I	Rush
Big Timber Creek	I	Rush
UT Smoky Hill River	I	Rush
UT Smoky Hill River	I	Rush
UT Sand Creek	I	Rush
UT Walnut Creek	I	Rush
UT Walnut Creek	I	Rush
Walnut Creek	P (Major)	Rush
UT Walnut Creek	I	Rush
Dry Walnut Creek	P (Minor)	Barton
UT Dry Walnut Creek	I	Barton
UT Dry Walnut Creek	I	Barton
UT Dry Walnut Creek	I	Barton
UT Dry Walnut Creek	I	Barton
Arkansas River[2]	P (Major)	Barton
Rattlesnake Creek	P (Minor)	Stafford
Peace Creek	P (Minor)	Stafford
UT N. Fork Ninnescah River	I	Stafford
UT N. Fork Ninnescah River	I	Stafford

Total Crossings

Intermittent: 33
Perennial (Minor): 5
Perennial (Major): 2

Table A-8 (concluded)
I = Intermittent; P (Minor) = Minor Perennial; UT = Unnamed Tributary

Stream	Flow	County
UT N. Fork Ninnescah River	I	Stafford
UT N. Fork Ninnescah River	I	Stafford
N. Fork Ninnescah River	P (Minor)	Stafford
UT N. Fork Ninnescah River	I	Stafford
UT Wolf Creek	I	Reno
UT Silver Creek	I	Reno
Silver Creek	P (Minor)	Reno
Goose Creek	P (Minor)	Kingman
UT S.Fork Ninnescah River	I	Kingman
UT Ninnescah Lake	I	Kingman
UT S.Fork Ninnescah River	I	Kingman
S.Fork Ninnescah River	P (Minor)	Kingman
UT S.Fork Ninnescah River	I	Kingman
Wild Run Creek	I	Kingman
UT S.Fork Ninnescah River	I	Kingman
Hunter Creek	I	Kingman
UT Red Creek	I	Kingman
UT Red Creek	I	Kingman
UT Red Creek	I	Kingman
Rosebud Creek	I	Kingman
UT Rosebud Creek	I	Kingman
Chikaskia River	P (Minor)	Kingman
UT Chikaskia River	I	Kingman
UT Chikaskia River	I	Harper
UT Spring Creek	I	Harper
UT Spring Creek	I	Harper
Spring Creek	I	Harper
Sand Creek	P (Minor)	Harper
UT Sand Creek	P (Minor)	Harper
UT Sand Creek	P (Minor)	Harper
Fall Creek	P (Minor)	Sumner
Fall Creek	P (Minor)	Sumner
UT Fall Creek	I	Sumner
UT Fall Creek	I	Sumner
Spring Creek	I	Sumner
UT Spring Creek	I	Sumner
UT Fall Creek	I	Sumner
UT Fall Creek	I	Sumner
UT Fall Creek	I	Sumner
Fall Creek	P (Minor)	Sumner
Bluff Creek	P (Minor)	Sumner

Total Crossings

Intermittent: 29
Perennial (Minor): 12

Table A-9 LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS THAT WOULD BE CROSSED BY THE PROPOSED ACTION THROUGH OKLAHOMA

I = Intermittent; P (Major) = Major Perennial; P (Minor) = Minor Perennial; UT = Unnamed Tributary; 2 = 404 permit required

Stream	Flow	County
UT Bluff Creek	I	Grant
UT Bluff Creek	I	Grant
Thompson Creek	I	Kay
UT Stink Creek	I	Kay
UT Stink Creek	I	Kay
Chikaskia River[2]	P (Major)	Kay
Chikaskia River	P (Minor)	Kay
Salt Fork Arkansas River[2]	P (Major)	Kay
Birds Nest Creek	I	Noble
UT Red Rock Creek	I	Noble
Red Rock Creek	P (Minor)	Noble
UT Red Rock Creek	I	Noble
Greasy Creek	I	Pawnee
Greasy Creek	I	Pawnee
UT Greasy Creek	I	Pawnee
Rock Creek	I	Pawnee
Walker Creek	I	Pawnee
UT Coal Creek	I	Pawnee
UT Coal Creek	I	Pawnee
Coon Creek	I	Pawnee
Arkansas River[2]	P (Major)	Osage
UT Arkansas River	I	Osage
UT Arkansas River	I	Osage
UT Arkansas River	I	Osage
UT Arkansas River	I	Osage
UT Sycamore Creek	I	Osage
UT Sycamore Creek	I	Osage
Sycamore Creek	P (Minor)	Osage
Bug Creek	P (Minor)	Osage
UT Bug Creek	I	Osage
Penn Creek	I	Osage
UT Penn Creek	I	Osage
Hominy Creek	P (Minor)	Osage
Mahala Creek	I	Osage
Sunset Creek	I	Osage
Sand Creek	I	Osage
UT Bull Creek	I	Osage
Bull Creek	I	Osage
UT Bull Creek	I	Osage
UT Bull Creek	I	Osage

Total Crossings

Intermittent: 32
Perennial (Minor): 5
Perennial (Major): 3

Table A-9 (continued)
I = Intermittent; P (Major) = Major Perennial; P (Minor) = Minor Perennial; B = Bayou; UT = Unnamed Tributary; 1 = Section 10 permit required; 2 = 404 permit required

Stream	Flow	County
UT Quapaw	I	Osage
Candy Creek	P (Minor)	Osage
UT Candy Creek	I	Washington
Bird Creek	I	Washington
UT Caney River	I	Washington
Caney River	P (Minor)	Rogers
Rabb Creek	I	Rogers
UT Rabb Creek	P (Minor)	Rogers
Fourmile Creek[2]	P (Minor)	Rogers
Verdigris River[2]	P (Major)	Rogers
Dog Creek	P (Minor)	Rogers
UT Lake Claremore	I	Rogers
UT Chouteau Creek	I	Rogers
UT Chouteau Creek	I	Mayes
UT Chouteau Creek	I	Mayes
Chouteau Creek	P (Minor)	Mayes
Brush Creek	P (Minor)	Mayes
UT Brush Creek	I	Mayes
UT Brush Creek	I	Mayes
Flat Rock Creek	P (Minor)	Wagoner
UT Fort Gibson Reservoir	P (Minor)	Wagoner
UT Arkansas River[1]	I	Wagoner
Neosho River[1]	P (Major)	Muskogee
Arkansas River	P (Major)	Muskogee
Coody Creek	P (Minor)	Muskogee
UT Coody Creek	P (Minor)	Muskogee
UT Arkansas River	P (Minor)	Muskogee
Spaniard Creek[1]	P (Major)	Muskogee
UT Arkansas River	P (Minor)	Muskogee
UT Dirty Creek	I	Muskogee
UT Dirty Creek	I	Muskogee
Arkansas River[1]	P (Major)	Muskogee
Illinois River[1]	P (Major)	Sequoyah
UT Little Sallisaw Creek	I	Sequoyah
Sallisaw Creek	P (Minor)	Sequoyah
Hog Creek	P (Minor)	Sequoyah
UT Hog Creek	P (Minor)	Sequoyah

Total Crossings

Intermittent: 15
Perennial (Minor): 16
Perennial (Major): 6

Table A-9 (concluded)
I = Intermittent; P (Major) = Major Perennial; P (Minor) = Minor Perennial; B = Bayou; UT = Unnamed Tributary; 1 = Section 10 permit required; 2 = 404 permit required

Stream	Flow	County
Little Sallisaw Creek	P (Minor)	Sequoyah
UT Little Sallisaw Creek	I	Sequoyah
UT Little Sallisaw Creek	I	Sequoyah
Big Skin Bayou	B	Sequoyah
UT Arkansas River	I	Sequoyah
Vian Creek	P (Minor)	Sequoyah
Little Vian Creek	P (Minor)	Sequoyah
Baron Fork River	P (Major)	

Total Crossings

Intermittent: 3
Perennial (Minor): 3
Perennial (Major): 1
Bayou: 1

Table A-10 LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS THAT WOULD BE CROSSED BY THE PROPOSED ACTION AND MARKET ALTERNATIVE THROUGH ARKANSAS
I = Intermittent; P (Major) = Major Perennial; P (Minor) = Minor Perennial; B = Bayou; UT = Unnamed Tributary; 1 = Section 10 permit required

Stream	Flow	County
Lee Creek[1]	P (Major)	Crawford
UT Lee Creek	P (Minor)	Crawford
UT Lee Creek	P (Minor)	Crawford
Frog Bayou[2]	P (Major)	Crawford
Little Frog Bayou	B	Crawford
UT Arkansas River	P (Minor)	Crawford
UT Arkansas River	P (Minor)	Crawford
Little Mulberry River[2]	P (Major)	Crawford
Mulberry River[1]	P (Major)	Crawford
UT Mulberry River	P (Minor)	Franklin
UT Arkansas River	I	Franklin
UT White Oak Creek	I	Franklin
UT White Oak Creek	I	Franklin
N. Fork White Oak Creek	P (Major)	Franklin
UT S. Fork White Oak Creek	I	Franklin
S. Fork White Oak Creek	I	Franklin
UT S. Fork White Oak Creek	I	Franklin
E. Fork Gar Creek	I	Franklin
UT McKinney Creek	I	Franklin
UT McKinney Creek	I	Franklin
UT McKinney Creek	I	Johnson
UT McKinney Creek	I	Johnson
UT McKinney Creek	I	Johnson
Horsehead Creek[2]	P (Major)	Johnson
UT E. Fork Horsehead Creek	I	Johnson
E. Fork Horsehead Creek[2]	P (Major)	Johnson
UT Spadra Creek	I	Johnson
UT Spadra Creek	I	Johnson
UT Spadra Creek	I	Johnson
Spadra Creek[2]	P (Major)	Johnson
UT Spadra Creek	I	Johnson
UT Little Piney Creek	I	Johnson
Little Piney Creek[2]	P (Major)	Johnson
Big Piney Creek	P (Major)	Johnson

Total Crossings

Intermittent: 18
Perennial (Minor): 5
Perennial (Major): 9
Bayou: 1

Table A-10 (continued)
I = Intermittent; P (Major) = Major Perennial; P (Minor) = Minor Perennial; B = Bayou; UT = Unnamed Tributary; 1 = Section 10 permit required

Stream	Flow	County
Illinois Bayou[2]	P (Major)	Pope
UT Gum Log Creek	I	Pope
UT Gum Log Creek	I	Pope
Gum Log Creek[2]	P (Major)	Pope
Kuhn Bayou	B	Conway
Arkansas River[1]	P (Major)	Conway
UT Cypress Creek	I	Conway
UT Cypress Creek	I	Conway
UT Cypress Creek	I	Perry
Cypress Creek[2]	P (Major)	Perry
Fourche La Fave River[1]	P (Major)	Perry
Maumelle River[2]	P (Major)	Pulaski
UT Lake Maumelle	I	Pulaski
Harris Brake Lake	P (Major)	Pulaski
Nolan Creek	I	Pulaski
Neal Creek	I	Pulaski
Little Maumelle River	I	Pulaski
UT Little Maumelle River	I	Pulaski
Fourche Creek	P (Major)	Saline
UT Fourche Creek	P (Minor)	Saline
UT Lorance Creek	I	Saline
UT Lorance Creek	I	Saline
UT Lorance Creek	I	Pulaski
Lorance Creek	P (Minor)	Saline
Maple Creek	I	Saline
UT Maple Creek	I	Saline
Clear Creek	P (Minor)	Saline
UT Clear Creek	I	Pulaski
UT Pennington Bayou	I	Pulaski
UT Turkey Creek	I	Grant
Turkey Creek	I	Jefferson
Tar Camp Creek	I	Jefferson
Love Creek	I	Jefferson
UT Eastwood Bayou	I	Jefferson
Eastwood Bayou	I	Jefferson
Caney Bayou	I	Jefferson
Bayou Bartholomew	I	Jefferson
Big Creek	I	Jefferson

Total Crossings

Intermittent: 26
Perennial (Minor): 3
Perennial (Major): 7
Bayou: 1

Table A-10 (concluded)
I = Intermittent; P (Major) = Major Perennial; P (Minor) = Minor Perennial; B = Bayou; UT = Unnamed Tributary; 1 = Section 10 permit required

Stream	Flow	County
Big Creek[2]	P (Minor)	Cleveland
Big Creek[2]	P (Major)	Cleveland
Saline River[1]	P (Major)	Cleveland
UT Saline River	P (Minor)	Cleveland
UT Saline River	P (Minor)	Cleveland
UT Saline River	I	Cleveland
UT Saline River	I	Bradley
UT Saline River	I	Bradley
Franklin Creek	I	Bradley
Brushy L'Aigle Creek	P (Minor)	Bradley
Grassy Pond Creek	I	Bradley
UT Grassy Pond Creek	I	Bradley
Snake Creek	P (Minor)	Bradley
Saline River[1]	P (Major)	Bradley
Brushy Creek	P (Minor)	Ashley
Coffee Creek	P (Minor)	Ashley
Coffee Creek	P (Minor)	Ashley
Coffee Creek	P (Minor)	Ashley

Total Crossings

Intermittent: 6
Perennial (Minor): 9
Perennial (Major): 3

Table A-11 LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS THAT WOULD BE CROSSED BY THE PROPOSED ACTION AND MARKET ALTERNATIVE THROUGH LOUISIANA

I = Intermittent; P (Major) = Major Perennial; P (Minor) = Minor Perennial; B = Bayou; UT = Unnamed Tributary; 1 = Section 10 permit required; 3 = Scenic river

Stream	Flow	Parish
Shiloh Creek	P (Minor)	Morehouse
UT Ouachita River	I	Morehouse
Hog Slough	I	Morehouse
Bayou de Butte	B	Morehouse
UT Ouachita River	I	Morehouse
UT Ouachita River	I	Morehouse
UT Ouachita River	I	Morehouse
Bayou Bartholomew[1,3]	P (Major)	Morehouse
UT Bayou Bartholomew	I	Morehouse
UT Bayou Bartholomew	I	Ouachita
UT Black Bayou Lake	I	Ouachita
Gourd Bayou	I	Ouachita
UT Gourd Bayou	I	Ouachita
UT Youngs Bayou	B	Ouachita
Petticoat Bayou	B	Ouachita
Petticoat Bayou	B	Ouachita
Petticoat Bayou	B	Ouachita
Prairie Bayou	I	Ouachita
Halfway Bayou	I	Ouachita
UT Halfway Bayou	I	Ouachita
UT Bayou Lafourche	I	Caldwell
Ouachita River[1]	P (Major)	Caldwell
UT Ouachita River	I	Caldwell
UT Black Bayou	I	Caldwell
UT Black Bayou	I	Caldwell
UT Black Bayou	I	Caldwell
UT Black Bayou	I	Caldwell
UT Black Bayou	I	Caldwell
Black Bayou	B	Caldwell
Chickasaw Creek	P (Minor)	LaSalle
Delaney Branch Tarven Creek	I	LaSalle
UT Tarven Creek	I	LaSalle
UT Cow Creek	P (Minor)	LaSalle
Bayou Funny Louis	B	LaSalle
UT Bayou Funny Louis	B	LaSalle
UT Trout Creek	I	LaSalle
UT Catahowla Lake	I	LaSalle

Total Crossings

Intermittent: 24
Perennial (Minor): 3
Perennial (Major): 2
Bayou: 8

Table A-11 (continued)
I = Intermittent; P (Major) = Major Perennial; P (Minor) = Minor Perennial; B = Bayou; UT = Unnamed Tributary; 1 = Section 10 permit required; 3 = Scenic river

Stream	Flow	Parish
Kitterlin Creek	P (Minor)	LaSalle
UT Kitterlin Creek	P (Minor)	LaSalle
UT Kitterlin Creek	P (Minor)	LaSalle
Little River[1,3]	P (Major)	LaSalle
UT Little River	I	Grant
UT Little River	I	Grant
UT Little River	I	Grant
UT Flagon Bayou	B	Rapides
Flagon Bayou	I	Rapides
Red River[1]	P (Major)	Rapides
Chatlin Lake Canal	P (Minor)	Rapides
Unnamed stream	P (Minor)	Rapides
Unnamed stream	P (Minor)	Rapides
Unnamed stream	P (Minor)	Rapides
Bayou Boeuf[1]	P (Major)	Rapides
Bayou Boeuf & Cocodrie Diversion Channel[1]	P (Major)	Rapides
UT Beaver Creek	I	Rapides
UT Cocodrie Lake	I	Rapides
Spring Creek[1,3]	P (Major)	Rapides
Little Spring Creek	P (Minor)	Rapides
UT Little Spring Creek	P (Minor)	Rapides
Clear Creek	P (Minor)	Rapides
McKemb Branch Bayou Cocodrie	B	Rapides
Bayou Cocodrie[1,3]	P (Major)	Evangeline
UT Bayou Cocodrie	B	Evangeline
UT Cypress Creek	P (Minor)	Evangeline
Cypress Creek	P (Minor)	Allen
Morris Branch Beaver Creek	P (Minor)	Allen
Beaver Creek	P (Minor)	Allen
UT Castor Creek	I	Allen
UT Calcasieu River	I	Allen
Bayou Blue	I	Allen
Unnamed bayou	B	Allen
Unnamed bayou	B	Allen
Unnamed bayou	B	Allen
UT Calcasieu River	P (Minor)	Allen
UT Calcasieu River	P (Minor)	Allen

Total Crossings

Intermittent: 9
Perennial (Minor): 16
Perennial (Major): 6
Bayou: 6

Table A-11 (concluded)
I = Intermittent; P (Major) = Major Perennial; P (Minor) = Minor Perennial; B = Bayou; UT = Unnamed Tributary; 1 = Section 10 permit required; 3 = Scenic river

Stream	Flow	Parish
UT Calcasieu River	P (Minor)	Allen
UT Calcasieu River	P (Minor)	Allen
Kinder Ditch	P (Minor)	Allen
Gum Bayou	B	Jefferson Davis
Serpent Bayou	B	Jefferson Davis
Serpent Bayou	B	Jefferson Davis
Serpent Bayou	B	Jefferson Davis
Serpent Bayou	B	Jefferson Davis
Unnamed canal	B	Jefferson Davis
Calcasieu River[1]	P (Major)	Calcasieu
UT Calcasieu River	P (Minor)	Calcasieu
Goldsmith Canal	B	Calcasieu
UT Little Indian Bayou	B	Calcasieu
Indian Bayou	B	Calcasieu
W. Fork Calcasieu River	P (Minor)	Calcasieu

Total Crossings

Perennial (Minor): 5
Perennial (Major): 1
Bayou: 9

Table A-12 LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS THAT WOULD BE CROSSED BY THE MARKET ALTERNATIVE THROUGH KANSAS
I = Intermittent; P (Minor) = Minor Perennial; UT = Unnamed Tributary

Stream	Flow	County
UT Beaver Creek	I	Decatur
UT Beaver Creek	I	Decatur
UT Beaver Creek	I	Decatur
UT Beaver Creek	I	Decatur
UT Sappa Creek	I	Decatur
UT Sappa Creek	I	Decatur
UT Sappa Creek	I	Decatur
UT Sappa Creek	I	Decatur
Sappa Creek	P (Minor)	Decatur
UT Sappa Creek	I	Decatur
UT Sappa Creek	I	Decatur
UT Sappa Creek	I	Decatur
UT Sappa Creek	I	Decatur
UT Spring Branch Sappa Creek	I	Decatur
Spring Branch Sappa Creek	I	Decatur
Long Branch Sappa Creek	I	Decatur
UT Long Branch Sappa Creek	I	Norton
UT Long Branch Sappa Creek	I	Norton
UT Long Branch Sappa Creek	I	Norton
UT Long Branch Sappa Creek	I	Norton
UT Long Branch Sappa Creek	I	Norton
UT Norton Reservoir	I	Norton
UT Norton Reservoir	I	Norton
UT Norton Reservoir	I	Norton
UT Norton Reservoir	I	Norton
UT Norton Reservoir	I	Norton
UT Norton Reservoir	I	Norton
UT Norton Reservoir	I	Norton
UT Norton Reservoir	I	Norton
UT Norton Reservoir	I	Norton
UT Norton Reservoir	I	Norton
UT Prairie Dog Creek	I	Norton
Prairie Dog Creek	P (Minor)	Norton
UT Prairie Dog Creek	I	Norton
UT Prairie Dog Creek	I	Norton
UT Prairie Dog Creek	I	Norton
Big Thunder Creek	I	Norton
UT N. Fork Solomon River	I	Norton
N. Fork Solomon River	P (Minor)	Norton
UT N. Fork Solomon River	I	Norton
UT N. Fork Solomon River	I	Norton
UT N. Fork Solomon River	I	Norton

Total Crossings

Intermittent: 39
Perennial (Minor): 3

Table A-12 (continued)
I = Intermittent; P (Minor) = Minor Perennial; UT = Unnamed Tributary

Stream	Flow	County
UT N. Fork Solomon River	I	Phillips
UT N. Fork Solomon River	I	Phillips
UT N. Fork Solomon River	I	Phillips
UT Bow Creek	I	Phillips
Bow Creek	P (Minor)	Phillips
Bow Creek	P (Minor)	Phillips
Bow Creek	P (Minor)	Rooks
UT Bow Creek	I	Rooks
UT S. Fork Solomon River	I	Rooks
UT S. Fork Solomon River	I	Rooks
UT S. Fork Solomon River	I	Rooks
UT S. Fork Solomon River	I	Rooks
UT S. Fork Solomon River	I	Rooks
Ash Creek	I	Rooks
UT Ash Creek	I	Rooks
S. Fork Solomon River	P (Minor)	Rooks
UT S. Fork Solomon River	I	Rooks
Box Elder Creek	I	Rooks
Robbers Roost	I	Rooks
Elm Creek	I	Rooks
UT Medicine Creek	I	Rooks
UT Medicine Creek	I	Rooks
UT Medicine Creek	I	Rooks
UT Medicine Creek	I	Rooks
UT Paradise Creek	I	Rooks
UT Paradise Creek	I	Rooks
UT Paradise Creek	I	Rooks
UT Paradise Creek	I	Rooks
UT Paradise Creek	I	Rooks
Paradise Creek	P (Minor)	Osborne
UT Paradise Creek	I	Osborne
Paradise Creek	P (Minor)	Osborne
Paradise Creek	P (Minor)	Osborne
Paradise Creek	P (Minor)	Osborne
Paradise Creek	P (Minor)	Osborne
Paradise Creek	P (Minor)	Osborne
UT Paradise Creek	I	Russell
UT Paradise Creek	I	Russell
UT Paradise Creek	I	Russell
Paradise Creek	P (Minor)	Russell
Paradise Creek	P (Minor)	Russell
UT Paradise Creek	I	Russell
UT Paradise Creek	I	Russell
Paradise Creek	P (Minor)	Russell

Total Crossings

Intermittent: 31
Perennial (Minor): 13

Table A-12 (continued)
I = Intermittent; P (Major) = Major Perennial; P (Minor) = Minor Perennial; UT = Unnamed Tributary; 2 = 404 permit required

Stream	Flow	County
UT Paradise Creek	I	Russell
UT Paradise Creek	I	Russell
UT Paradise Creek	I	Russell
UT Saline River	I	Russell
Saline River[2]	P (Major)	Russell
UT Saline River	I	Russell
UT Saline River	I	Russell
UT Saline River	P (Minor)	Russell
UT Saline River	I	Russell
UT Saline River	I	Russell
UT Wilson Lake	I	Russell
UT Wilson Lake	I	Russell
UT Wilson Lake	I	Russell
UT Smoky Hill River	I	Russell
UT Smoky Hill River	I	Russell
UT Smoky Hill River	I	Russell
UT Smoky Hill River	I	Russell
UT Smoky Hill River	I	Russell
Unnamed stream	I	Russell
UT Smoky Hill River	I	Russell
Smoky Hill River	P (Minor)	Russell
UT Smoky Hill River	I	Ellsworth
Blood Creek	P (Minor)	Ellsworth
Wolf Creek	I	Ellsworth
UT Smoky Hill River	I	Ellsworth
UT Smoky Hill River	I	Ellsworth
UT Turkey Creek	I	Ellsworth
Turkey Creek	I	Ellsworth
UT Oxide Creek	I	Ellsworth
Oxide Creek	P (Minor)	Ellsworth
UT Ash Creek	I	Ellsworth
UT Ash Creek	I	Ellsworth
UT Ash Creek	I	Ellsworth
UT Ash Creek	I	Ellsworth
UT Ash Creek	I	Ellsworth
UT Ash Creek	I	Ellsworth
UT Thompson Creek	I	Ellsworth
UT Thompson Creek	I	Ellsworth
UT Thompson Creek	I	Ellsworth
UT Thompson Creek	I	Ellsworth

Total Crossings

Intermittent: 35
Perennial (Minor): 4
Perennial (Major): 1

Table A-12 (continued)
I = Intermittent; P (Minor) = Minor Perennial; UT = Unnamed Tributary

Stream	Flow	County
UT Little Arkansas River	I	Ellsworth
UT Little Arkansas River	I	Ellsworth
UT Little Arkansas River	I	Ellsworth
UT Little Arkansas River	I	Rice
UT Little Arkansas River	I	Rice
UT Little Arkansas River	I	Rice
UT Little Arkansas River	I	Rice
Horse Creek	I	Rice
UT Horse Creek	I	Rice
UT Little Arkansas River	P (Minor)	Rice
UT Little Arkansas River	I	Rice
UT Little Arkansas River	I	Rice
N. Fork Little Arkansas River	I	Rice
Lone Tree Creek	P (Minor)	McPherson
UT Wolf Creek	I	McPherson
Wolf Creek	P (Minor)	McPherson
UT Blaze Fork Little Arkansas River	I	McPherson
UT Blaze Fork Little Arkansas River	I	McPherson
UT Blaze Fork Little Arkansas River	I	McPherson
Blaze Fork Little Arkansas River	P (Minor)	McPherson
UT Turkey Creek	I	Harvey
Turkey Creek	P (Minor)	Harvey
Turkey Creek	P (Minor)	Harvey
Turkey Creek	P (Minor)	Harvey
Sand Creek	P (Minor)	Harvey
UT Little Arkansas River	I	Harvey
Black Kettle Creek	P (Minor)	Harvey
West Emma Creek	P (Minor)	Harvey
Middle Emma Creek	P (Minor)	Harvey
Sand Creek	P (Minor)	Harvey
E. Fork Jester Creek	P (Minor)	Harvey
UT Jester Creek	I	Harvey
W. Fork Chisholm Creek	I	Sedgwick
Chisholm Creek	I	Sedgwick
UT Chisholm Creek	I	Sedgwick
Whitewater Creek	I	Sedgwick

Total Crossings

Intermittent: 23
Perennial (Minor): 13

Table A-12 (concluded)
I = Intermittent; P (Minor) = Minor Perennial; UT = Unnamed Tributary

Stream	Flow	County
Dry Creek	P (Minor)	Butler
Dry Creek	P (Minor)	Butler
Dry Creek	P (Minor)	Butler
UT Dry Creek	I	Butler
Dry Creek	P (Minor)	Butler
Little Walnut River	P (Minor)	Butler
Muddy Creek	P (Minor)	Butler
UT Rock Creek	I	Butler
UT Rock Creek	I	Butler
UT Rock Creek	I	Butler
Rock Creek	P (Minor)	Butler
Dutch Creek	P (Minor)	Cowley
UT Dutch Creek	I	Cowley
Timber Creek	P (Minor)	Cowley
UT Timber Creek	I	Cowley
Grouse Creek	P (Minor)	Cowley
UT Grouse Creek	P (Minor)	Cowley
UT Otter Creek	I	Cowley
Otter Creek	P (Minor)	Cowley
UT Otter Creek	I	Cowley
Caney River	P (Minor)	Chautauqua
Turkey Creek	P (Minor)	Chautauqua
Spring Branch	I	Chautauqua
Grant Creek	P (Minor)	Chautauqua
UT Sycamore Creek	I	Chautauqua
Sycamore Creek	I	Chautauqua

Total Crossings

Intermittent: 11
Perennial (Minor): 15

Table A-13 LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS THAT WOULD BE CROSSED BY THE MARKET ALTERNATIVE THROUGH OKLAHOMA

I = Intermittent; P (Major) = Major Perennial; P (Minor) = Minor Perennial; UT = Unnamed Tributary; 1 = Section 10 permit required; 2 = 404 permit required); 3 = Natural and scenic river

Stream	Flow	County
Caney River	P (Minor)	Osage
Buck Creek	P (Minor)	Osage
Pond Creek	I	Osage
Spring Creek	I	Osage
Birch Creek	I	Osage
Mission Creek	I	Osage
UT Mission Creek	I	Osage
UT Buck Creek	I	Osage
UT Butler Creek	I	Osage
UT Turkey Creek	I	Osage
Turkey Creek	I	Osage
Sand Creek	P (Minor)	Osage
Caney River	P (Minor)	Washington
Caney River	P (Minor)	Washington
Caney River	P (Minor)	Washington
Caney River	P (Minor)	Washington
Caney River	P (Minor)	Washington
Buck Creek	I	Rogers
Rabb Creek	I	Rogers
Fourmile Creek	P (Minor)	Rogers
Verdigris River[2]	P (Major)	Rogers
Dog Creek	P (Minor)	Rogers
UT Dog Creek	I	Rogers
UT Lake Claremore	I	Rogers
UT Chouteau Creek	I	Rogers
UT Chouteau Creek	I	Mayes
Neosho River[2]	P (Major)	Mayes
UT Neosho River	I	Mayes
Snake Creek	I	Mayes
Spring Creek	P (Minor)	Mayes
Blackbird Creek	I	Cherokee
UT Fourteenmile Creek	I	Cherokee
Fourteenmile Creek	I	Cherokee
Double Spring Creek	I	Cherokee
UT Illinois River	I	Cherokee
Illinois River[1,3]	P (Major)	Cherokee
Baron Fork[2,3]	P (Minor)	Cherokee

Total Crossings

Intermittent: 22
Perennial (Minor): 12
Perennial (Major): 3

Table A-13 (concluded)
P (Minor) = Minor Perennial; UT = Unnamed Tributary; 1 = Section 10 permit required; 2 = 404 permit required); 3 = Natural and scenic river

Stream	Flow	County
UT Caney Creek	P (Minor)	Cherokee
Caney Creek	P (Minor)	Cherokee
UT Caney Creek	P (Minor)	Cherokee
UT Caney Creek	I	Adair
UT Caney Creek	I	Adair
UT Sallisaw Creek	I	Adair
Sallisaw Creek	P (Minor)	Adair
UT Sallisaw Creek	P (Minor)	Adair
UT Lee Creek	I	Sequoyah
Lee Creek	P (Minor)	Sequoyah
UT Lee Creek	P (Minor)	Sequoyah
Lee Creek[1,3]	P (Minor)	Sequoyah

Total Crossings

Intermittent: 4
Perennial (Minor): 8

Table A-14 LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS THAT WOULD BE CROSSED BY THE MARKET ALTERNATIVE THROUGH ARKANSAS
P (Minor) = Minor Perennial; B = Bayou; UT = Unnamed Tributary

Stream	Flow	County
UT Lee Creek	P (Minor)	Crawford
UT Lee Creek	P (Minor)	Crawford
W. Cedar Creek	P (Minor)	Crawford
Frog Bayou	B	Crawford
Little Frog Bayou	B	Crawford
*		

* From approximately MP 871.5 the Market Alternative slurry pipeline would be identical to the Proposed Action slurry line and would serve the same markets in Arkansas and Louisiana.

Total Crossings

Perennial (Minor): 3
Bayou: 2

Table A-15 LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS THAT WOULD BE CROSSED BY THE CYPRESS BEND LATERAL THROUGH ARKANSAS
I = Intermittent; P (Major) = Major Perennial; P (Minor) = Minor Perennial; B = Bayou; UT = Unnamed Tributary; 1 = Section 10 permit required

Stream	Flow	County
Love Creek	I	Jefferson
UT Eastwood Bayou	I	Jefferson
Eastwood Bayou	I	Jefferson
Caney Bayou	I	Jefferson
Bayou Bartholomew	I	Jefferson
UT Bayou Bartholomew	I	Jefferson
Boggy Bayou	I	Jefferson
UT Bayou Bartholomew	I	Jefferson
UT Bayou Bartholomew	I	Lincoln
UT Bayou Bartholomew	I	Lincoln
Turtle Creek	I	Lincoln
Flat Creek	I	Lincoln
Bayou Bartholomew	B	Lincoln
UT Bayou Bartholomew	B	Lincoln
UT Bayou Bartholomew	B	Lincoln
UT Bayou Bartholomew	B	Lincoln
UT Bayou Bartholomew	B	Lincoln
UT Bayou Bartholomew	B	Lincoln
UT Bayou Bartholomew	B	Lincoln
Little Wagon Bayou	B	Desha
Choctaw Bayou	B	Desha
Little Wagon Bayou	B	Desha
Cypress Creek Channel #19	P (Minor)	Desha
Amos Bayou	B	Desha
UT Boggy Bayou	B	Desha
UT Boggy Bayou	B	Desha
*Mississippi River[1]	P (Major)	Desha

* A barge loading facility would be built in the Mississippi River if the Pipeline-Barge Alternative were constructed.

Total Crossings

Intermittent: 12
Perennial (Minor): 1
Perennial (Major): 1
Bayou: 13

Table A-16 LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS THAT WOULD BE CROSSED BY THE BATON ROUGE EXTENSION THROUGH LOUISIANA
I = Intermittent; P (Major) = Major Perennial; P (Minor) = Minor Perennial; B = Bayou; UT = Unnamed Tributary; 1 = Section 10 permit required

Stream	Flow	County
False River Canal	P (Minor)	Pointe Coupee
The Chenal	P (Minor)	Pointe Coupee
Stumpy Bayou	I	Pointe Coupee
UT Grand Bayou	B	West Baton Rouge
UT Grand Bayou	B	West Baton Rouge
UT Grand Bayou	B	West Baton Rouge
Mississippi River[1]	P (Major)	East Baton Rouge

Total Crossings

Intermittent: 1
Perennial (Minor): 2
Perennial (Major): 1
Bayou: 3

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Table A-17 LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS THAT WOULD BE CROSSED BY THE WILTON EXTENSION THROUGH LOUISIANA

I = Intermittent; P (Major) = Major Perennial; P (Minor) = Minor Perennial; B = Bayou; UT = Unnamed Tributary; 1 = Section 10 permit required

Stream	Flow	County
False River Canal	P (Minor)	Pointe Coupee
The Chenal	P (Minor)	Pointe Coupee
Stumpy Bayou	I	Pointe Coupee
UT Grand Bayou	B	West Baton Rouge
UT Grand Bayou	B	West Baton Rouge
UT Grand Bayou	B	West Baton Rouge
UT Choctaw Bayou	B	West Baton Rouge
UT Choctaw Bayou	B	West Baton Rouge
Port Allen Canal[1]	P (Major)	West Baton Rouge
Choctaw Basin Canal	P (Minor)	West Baton Rouge
UT Bayou Baurbeaux	B	West Baton Rouge
UT Bayou Baurbeaux	B	West Baton Rouge
UT Bayou Baurbeaux	B	West Baton Rouge
Bayou Baurbeaux	B	West Baton Rouge
UT Wilbert Canal	P (Minor)	Iberville
Wilbert Canal	P (Minor)	Iberville
Plaquemine Bayou	B	Iberville
Plaquemine Bayou[1]	P (Major)	Iberville
UT Bayou Butte	B	Iberville
Bayou Butte	B	Iberville
Bayou Gould	B	Iberville
Bayou Tigre	B	Iberville
Bayou Sigur	B	Iberville
UT Bayou Sigur	B	Ascension
Bayou Bijou	B	Ascension
Bayou Lafourche[1]	P (Major)	Ascension
Bayou Verret	B	Ascension
UT Bayou Verret	B	Ascension
UT Bayou Verret	B	St. James
UT Bayou Verret	B	St. James
UT Bayou Verret	B	St. James
UT Bayou Verret	B	St. James
UT Bayou Verret	B	St. James
UT Bayou Verret	B	St. James
UT Bayou Verret	B	St. James
UT Bayou Verret	B	St. James
Unnamed Bayou	B	St. James
Unnamed Bayou	B	St. James
Mississippi River[1]	P (Major)	St. James

Total Crossings

Intermittent: 1
Perennial (Minor): 5
Perennial (Major): 4
Bayou: 29

Table A-18 LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS THAT WOULD BE CROSSED BY THE NEW ROADS LATERAL THROUGH LOUISIANA

P (Major) = Major Perennial; P (Minor) = Minor Perennial; B = Bayou; UT = Unnamed Tributary; 1 = Section 10 permit required; 2 = 404 permit required

Stream	Flow	County
UT Chatlin Lake Canal	P (Minor)	Rapides
UT Chatlin Lake Canal	P (Minor)	Rapides
UT Chatlin Lake Canal	P (Minor)	Rapides
UT Chatlin Lake Canal	P (Minor)	Rapides
Bayou Clear	B	Avoyelles
UT Bayou Rouge	B	Avoyelles
UT Bayou Rouge	B	Avoyelles
UT Black Water Bayou	B	Avoyelles
UT Bayou Rouge	B	St. Laundry
Bayou des Glaises Diversion Channel[2]	P (Major)	St. Laundry
Bayou Jack	B	St. Laundry
UT Bayou Jack	B	St. Laundry
UT Bayou Rouge	B	St. Laundry
Bayou Rouge	B	St. Laundry
UT Bayou Rouge	B	St. Laundry
UT Bayou Rouge	B	St. Laundry
UT Bayou Rouge	B	St. Laundry
Atchafalaya River[1]	P (Major)	Pointe Coupee
Johnson Bayou	B	Pointe Coupee
Cowhead Bayou	B	Pointe Coupee
Bayou Fordouche	B	Pointe Coupee
Bayou Fordouche[2]	P (Major)	Pointe Coupee
UT Bayou Portage	B	Pointe Coupee
UT Bayou Portage	B	Pointe Coupee
UT Bayou Portage	B	Pointe Coupee
Bayou Baree	B	Pointe Coupee

Total Crossings

Perennial (Minor): 4
Perennial (Major): 3
Bayou: 19

Table A-19 LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS THAT WOULD BE CROSSED BY THE BOYCE LATERAL THROUGH LOUISIANA
I = Intermittent; P (Minor) = Minor Perennial; B = Bayou; UT = Unnamed Tributary

Stream	Flow	County
Diversion Channel	P (Minor)	Rapides
Diversion Channel	P (Minor)	Rapides
Unnamed Bayou	B	Rapides
Middle Bayou	B	Rapides
UT Bayou Boeuf	B	Rapides
UT Bayou Boeuf	B	Rapides
UT Bayou Boeuf	B	Rapides
Bayou Rapides	B	Rapides
UT Bayou Rapides	I	Rapides
UT Fish Lake	I	Rapides
Bayou Jean de Jean	B	Rapides

Total Crossings

Intermittent: 2
Perennial (Minor): 2
Bayou: 7

Table A-20 LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS THAT WOULD BE CROSSED BY THE INDEPENDENCE LATERAL THROUGH ARKANSAS
I = Intermittent; P (Major) = Major Perennial; P (Minor) = Minor Perennial; UT = Unnamed Tributary; I = Section 10 permit required

Stream	Flow	County
Point Remove Creek[1]	P (Major)	
W. Fork Point Remove Creek[2]	P (Major)	Pope
UT W. Fork Point Remove Creek	I	Conway
UT W. Fork Point Remove Creek	I	Conway
UT E. Fork Point Remove Creek	I	Conway
E. Fork Point Remove Creek[2]	P (Major)	Conway
UT E. Fork Point Remove Creek	I	Conway
UT E. Fork Point Remove Creek	I	Conway
UT E. Fork Point Remove Creek	I	Conway
UT Hogan's Creek	I	Conway
UT Hogan's Creek	I	Conway
UT Pine Mountain Creek	I	Van Buren
UT Pine Mountain Creek	I	Van Buren
UT Pine Mountain Creek	I	Van Buren
N. Fork Cadron Creek[2]	P (Major)	Van Buren
UT N. Fork Cadron Creek	I	Van Buren
UT N. Fork Cadron Creek	I	Van Buren
UT Cadron Creek	I	Cleburne
Greers Ferry Lake	P (Major)	
Cove Creek	I	Cleburne
UT Little Red River	I	Cleburne
UT Little Red River	I	Cleburne
Little Red River[2]	P (Major)	Cleburne
Wilburn Creek	I	Cleburne
Big Creek[2]	P (Major)	Independence
Elbow Creek	I	Independence
UP Tenmile Creek	I	Independence
UP Tenmile Creek	I	Independence
UP Departee Creek	I	Independence
UP Departee Creek	I	Independence
UP Departee Creek	I	Independence
UP Departee Creek	I	Independence
Unnamed stream	P (Minor)	Independence
White River[1]	P (Major)	Independence

Total Crossings

Intermittent: 25
Perennial (Minor): 1
Perennial (Major): 8

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Table A-21 LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS THAT WOULD BE CROSSED BY THE COLORADO ALTERNATIVE THROUGH WYOMING

I = Intermittent; UT = Unnamed Tributary

Stream	Flow	County
UT Little Thunder Creek	I	Campbell
Little Thunder Creek	I	Campbell
UT Little Thunder Creek	I	Campbell
UT Little Thunder Creek	I	Campbell
UT Piney Creek	I	Weston
UT Piney Creek	I	Weston
UT Piney Creek	I	Weston
UT Frog Creek	I	Weston
UT Frog Creek	I	Weston
UT Frog Creek	I	Weston
UT Frog Creek	I	Weston
Unnamed stream	I	Weston
UT Keyton Creek	I	Weston
Keyton Creek	I	Weston
Horse Creek	I	Converse
Cheyenne River	I	Converse
UT Sheep Creek	I	Converse
UT Sheep Creek	I	Converse
UT Wagon Hound Creek	I	Converse
UT Cow Creek	I	Converse
UT Cow Creek	I	Converse
Cow Creek	I	Converse
UT Cow Creek	I	Niobrara
UT Cow Creek	I	Niobrara
Little Cow Creek	I	Niobrara
UT Little Cow Creek	I	Niobrara
UT Lightning Creek	I	Niobrara
UT Lightning Creek	I	Niobrara
UT Lightning Creek	I	Niobrara
UT Lightning Creek	I	Niobrara
Lightning Creek	I	Niobrara
Twentymile Creek	I	Niobrara
UT Twentymile Creek	I	Niobrara
UT Twentymile Creek	I	Niobrara
UT Twentymile Creek	I	Niobrara
UT Little Lightning Creek	I	Niobrara
UT Little Lightning Creek	I	Niobrara
UT Little Lightning Creek	I	Niobrara
UT Little Lightning Creek	I	Niobrara
UT Little Lightning Creek	I	Niobrara
Little Lightning Creek	I	Niobrara
Lance Creek	I	Niobrara
UT Lance Creek	I	Niobrara

Total Crossings

Intermittent: 43

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Table A-21 (concluded)
I = Intermittent; P (Major) = Major Perennial; P (Minor) = Minor Perennial; UT = Unnamed Tributary; 2 = 404 permit required

Stream	Flow	County
UT Bliss Creek	I	Niobrara
UT Muddy Creek	I	Niobrara
UT Muddy Creek	I	Niobrara
UT Muddy Creek	I	Niobrara
UT Muddy Creek	I	Niobrara
Willow Creek	I	Niobrara
Unnamed stream	I	Goshen
Unnamed stream	I	Goshen
UT Broom Creek	I	Goshen
UT Broom Creek	I	Goshen
Unnamed stream	I	Goshen
Unnamed stream	I	Goshen
Unnamed stream	I	Goshen
Unnamed stream	I	Goshen
Unnamed stream	I	Goshen
Unnamed stream	I	Goshen
UT North Platte River	I	Goshen
UT North Platte River	I	Goshen
UT North Platte River	I	Goshen
UT North Platte River	I	Goshen
UT Molly Fork	I	Goshen
Interstate Canal	P (Minor)	Goshen
North Platte River[2]	P (Major)	Goshen
Laramie River	P (Minor)	Goshen
Fort Laramie Canal	P (Minor)	Goshen
Deer Creek	I	Goshen
Cherry Creek	I	Goshen
Unnamed stream	I	Goshen
Unnamed stream	I	Goshen
Box Elder Creek	I	Goshen
Unnamed stream	I	Goshen
Fox Creek	P (Minor)	Goshen
Bear Creek	P (Minor)	Goshen
Spring Run	I	Goshen
Horse Creek	P (Minor)	Laramie
UT Horse Creek	I	Laramie
Sprager Creek	I	Laramie
Sprager Creek	I	Laramie
Sprager Creek	I	Laramie
Unnamed stream	I	Laramie
Unnamed stream	I	Laramie
Lodgepole Creek	P (Minor)	Laramie
Muddy Creek	I	Laramie

Total Crossings

Intermittent: 35
Perennial (Minor): 7
Perennial (Major): 1

Table A-22 LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS THAT WOULD BE CROSSED BY THE COLORADO ALTERNATIVE THROUGH COLORADO

I = Intermittent; P (Major) = Major Perennial; P (Minor) = Minor Perennial; UT = Unnamed Tributary; 2 = 404 permit required

Stream	Flow	County
Unnamed stream	I	Weld
UT North Pawnee Creek	I	Weld
UT North Pawnee Creek	I	Weld
UT North Pawnee Creek	I	Weld
UT North Pawnee Creek	I	Weld
Cottonwood Creek	I	Weld
Pawnee Creek	I	Weld
UT Pawnee Creek	I	Weld
UT Pawnee Creek	I	Weld
UT Pawnee Creek	I	Weld
Rawhide Creek	I	Logan
UT Pawnee Creek	I	Logan
UT Pawnee Creek	I	Logan
Sand Creek	I	Logan
North Sterling Canal	P (Minor)	Logan
Pawnee Ditch	P (Minor)	Logan
South Platte River[2]	P (Major)	Logan
Davis Brothers Ditch	P (Minor)	Logan
Unnamed stream	I	Washington
Unnamed stream	I	Washington
Unnamed stream	I	Washington
Unnamed stream	I	Washington
UT Rock Creek	I	Washington
UT Rock Creek	I	Washington
Rock Creek	I	Washington
Surveyor Creek	I	Yuma
Chief Creek	I	Yuma
North Fork Republican River	P (Minor)	Yuma
UT Dry Willow Creek	I	Yuma
UT Dry Willow Creek	I	Yuma
UT Dry Willow Creek	I	Yuma
Arikaree River	P (Minor)	Yuma
UT Arikaree River	I	Yuma

Total Crossings

Intermittent: 27
Perennial (Minor): 5
Perennial (Major): 1

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Table A-23 LOCATION AND FLOW CHARACTERISTICS OF STREAMS AND RIVERS THAT WOULD BE CROSSED BY THE COLORADO ALTERNATIVE THROUGH KANSAS

I = Intermittent; P (Minor) = Minor Perennial; UT = Unnamed Tributary

Stream	Flow	County
UT Cherry Creek	I	Cheyenne
UT Cherry Creek	I	Cheyenne
Cherry Creek	I	Cheyenne
UT S. Fork Republican River	I	Cheyenne
S. Fork Republican River	I	Cheyenne
UT S. Fork Republican River	I	Cheyenne
W. Fork Sand Creek	I	Cheyenne
UT W. Fork Sand Creek	I	Cheyenne
UT Sand Creek	I	Cheyenne
Sand Creek	I	Cheyenne
Little Beaver Creek	I	Cheyenne
Beaver Creek	P (Minor)	Sherman
UT Beaver Creek	I	Sherman
UT Beaver Creek	I	Sherman
M. Fork Sappa Creek	I	Thomas
S. Fork Sappa Creek	I	Thomas
UT S. Fork Sappa Creek	I	Thomas
UT Prairie Dog Creek	I	Thomas
Prairie Dog Creek	I	Thomas
N. Fork Solomon River	I	Thomas
UT S. Fork Solomon River	I	Thomas
S. Fork Solomon River	I	Thomas
UT S. Fork Solomon River	I	Thomas
UT S. Fork Solomon River	I	Thomas
UT S. Fork Solomon River	I	Thomas
UT S. Fork Solomon River	I	Thomas
UT S. Fork Solomon River	I	Thomas
UT N. Fork Saline River	I	Thomas
UT N. Fork Saline River	I	Thomas
UT N. Fork Saline River	I	Thomas
UT Saline River	I	Thomas
UT Saline River	I	Sheridan
Saline River	I	Sheridan
UT Saline River	I	Sheridan
UT Saline River	I	Sheridan
UT Saline River	I	Sheridan
UT Saline River	I	Sheridan
UT Saline River	I	Sheridan
UT Saline River	I	Sheridan
UT Saline River	I	Sheridan
UT Big Creek	I	Gove
UT Big Creek	I	Gove
UT Big Creek	I	Gove
UT Big Creek	I	Gove
UT Big Creek	I	Gove

Total Crossings

Intermittent: 44
Perennial (Minor): 1

D#4 34/31 - 2
Table A-23 (continued)
I = Intermittent; P (Minor) = Minor Perennial; UT = Unnamed Tributary

Stream	Flow	County
UT Big Creek	I	Gove
UT Big Creek	I	Gove
UT Big Creek	I	Gove
UT Big Creek	I	Gove
Big Creek	I	Gove
Big Creek	I	Gove
Big Creek	I	Gove
Big Creek	I	Gove
Big Creek	I	Gove
UT Big Creek	I	Gove
UT Big Creek	I	Trego
Big Creek	I	Trego
E. Branch Downer Creek	I	Trego
UT Cedar Bluff Reservoir	I	Trego
UT Cedar Bluff Reservoir	I	Trego
UT Big Creek	I	Trego
UT Cedar Bluff Reservoir	I	Trego
UT Cedar Bluff Reservoir	I	Trego
UT Big Creek	I	Trego
UT Smokey Hill River	I	Trego
UT Smokey Hill River	I	Trego
UT Smokey Hill River	I	Trego
UT Smokey Hill River	I	Trego
UT Smokey Hill River	I	Trego
UT Smokey Hill River	I	Trego
UT Smokey Hill River	I	Ellis
UT Smokey Hill River	I	Ellis
UT Smokey Hill River	I	Ellis
UT Smokey Hill River	I	Ellis
UT Smokey Hill River	I	Ellis
UT Smokey Hill River	I	Ellis
UT Smokey Hill River	I	Ellis
UT Smokey Hill River	I	Ellis
UT Smokey Hill River	I	Ellis
UT Smokey Hill River	I	Ellis
UT Smokey Hill River	I	Ellis
UT Smokey Hill River	I	Ellis
UT Smokey Hill River	I	Ellis
UT Smokey Hill River	I	Ellis
UT Smokey Hill River	I	Ellis
Smokey Hill River	I	Ellis
UT Smokey Hill River	I	Rush
UT Smokey Hill River	I	Rush
Duck Creek	I	Rush
UT Duck Creek	I	Rush

Total Crossings

Intermittent: 46

D#6 34/31 - 3
Table A-23 (concluded)
I = Intermittent; P (Minor) = Minor Perennial; UT = Unnamed Tributary

Stream	Flow	County
Eagle Creek	I	Rush
UT Smokey Hill River	I	Barton
UT Landon Creek	I	Barton
Landon Creek	P (Minor)	Barton
UT Sellens Creek	P (Minor)	Barton
Sellens Creek	P (Minor)	Barton
UT Sellens Creek	I	Barton
UT Sellens Creek	I	Barton
UT Deception Creek	I	Barton
UT Deception Creek	I	Barton
Deception Creek	P (Minor)	Barton
UT Deception Creek	I	Barton
Unnamed stream	I	Barton
UT Cow Creek	I	Barton
Cow Creek	P (Minor)	Barton
UT Cow Creek	P (Minor)	Barton
UT Cow Creek	I	Barton
UT Cow Creek	I	Barton
UT Cow Creek	I	Barton
UT Calf Creek	I	Barton
UT Calf Creek	I	Ellsworth
UT Calf Creek	I	Ellsworth
Calf Creek	I	Ellsworth
JT Plum Creek	P (Minor)	Ellsworth
IT Plum Creek	I	Ellsworth
lum Creek	P (Minor)	Rice
UT Lost Creek	I	Rice
UT Lost Creek	I	Rice
Lost Creek	P (Minor)	Rice
UT Lost Creek	I	Rice
UT Lost Creek	I	Rice
UT Lost Creek	I	Rice
UT Lost Creek	I	Rice
Little Cow Creek	P (Minor)	Rice
UT Little Cow Creek	I	Rice
UT Little Cow Creek	I	Rice
UT Little Cow Creek	I	Rice
UT Little Cow Creek	I	Rice
UT Little Arkansas River	I	Rice
UT Little Arkansas River	I	Rice
UT Little Arkansas River	I	Rice
Little Arkansas River	P (Major)	Rice
Little Arkansas River	P (Minor)	Rice
Little Arkansas River	P (Minor)	Rice
Horse Creek	I	Rice

Total Crossings

Intermittent: 32
Perennial (Minor): 12
Perennial (Major): 1

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